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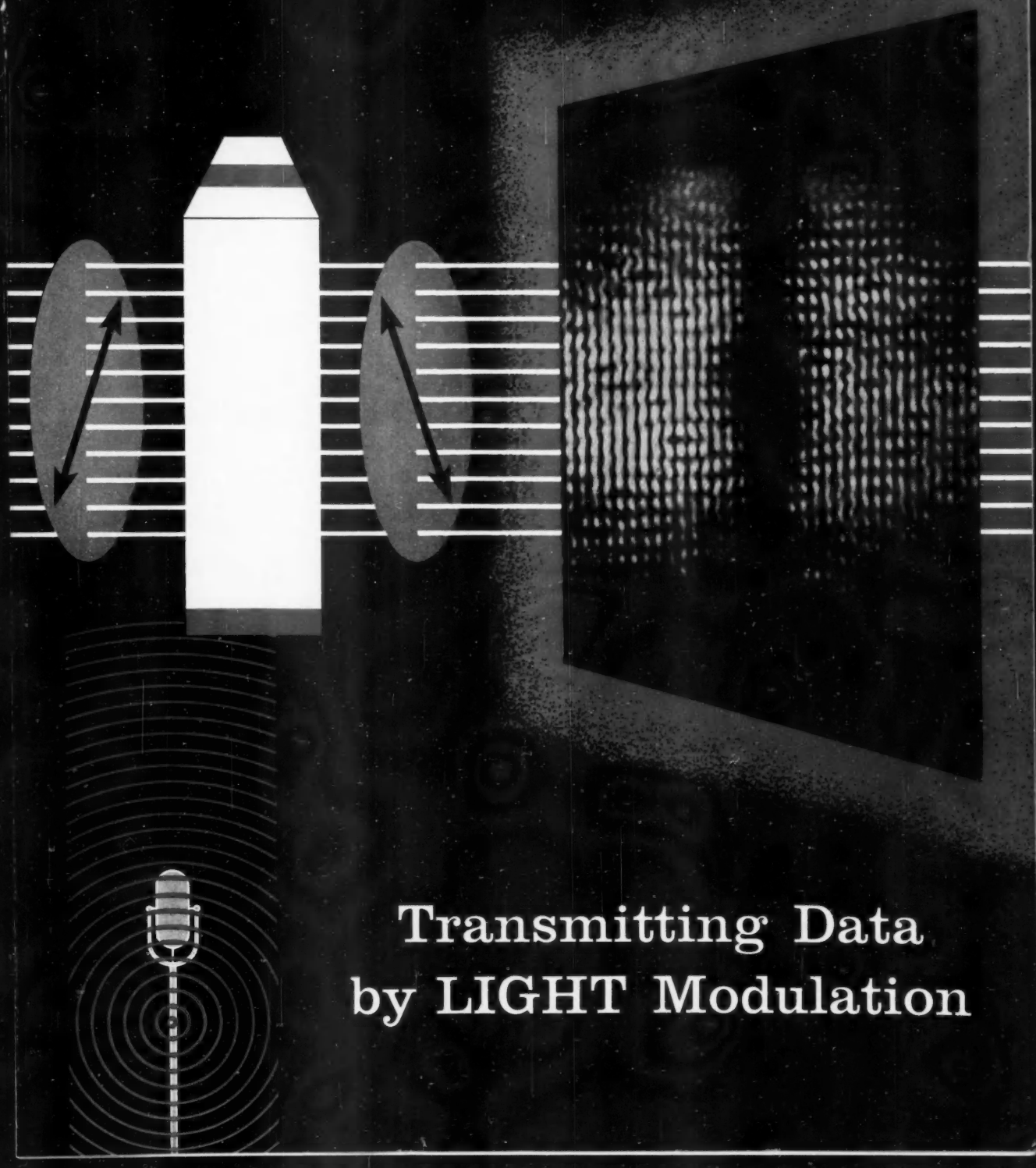
PRICE 50 CENTS

JULY 1957

Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS



Transmitting Data by LIGHT Modulation

EXPERIENCE AND VERSATILITY have earned for Librascope a position of leadership in the design, development and manufacture of computers and controls for military and industrial applications. Through extensive experience in the combination of electronic, magnetic, mechanical and optical design concepts, Librascope can offer an impressive capacity for achievement in the development of precision instrumentation. This knowledge, gained over a twenty year period, can be focused on *your* computer-control problem... with marked success! Your inquiry is invited.

Engineers capable of significant contributions are invited to write Glen Seltzer, Employment Manager

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SPEAKING OF BALANCE

Only GEDA gives you a self-checking Automatic Stabilization System

It's the first really *different* drift stabilization and error detection system for large-scale analog computers. It's automatic—it's continuous—and it has a built-in watchdog.

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Each modular plug-in unit provides 83 time-sharing channels for continuous drift stabilization of direct coupled amplifiers *anywhere in the computer*. All stabilizer channels can be quickly verified *at one central point* with the exclusive GEDA test error signal check. And, only the GEDA Automatic Stabilization System gives you continuous automatic pilot channel monitoring.

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The Automatic Stabilization System is but one of the advanced design and engineering features which make the GEDA A-14 Series the most accurate and flexible analog computers ever available. Get the complete GEDA A-14 story today. Write: Goodyear Aircraft Corporation, Dept. 931GG, Akron 15, Ohio.

• • •

For detailed technical data on the new GEDA A-14 Automatic Stabilization System, ask for your personal copy of the paper: "A Reliable Method Of Drift Stabilization And Error Detection In Large-Scale Analog Computers."

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ANALOG COMPUTERS

GOODYEAR AIRCRAFT

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Tubeless magnetic amplifier

AC Line Regulator features ±0.25% regulation accuracy

FOR ANY COMBINATION OF LINE OR LOAD

NO TUBES
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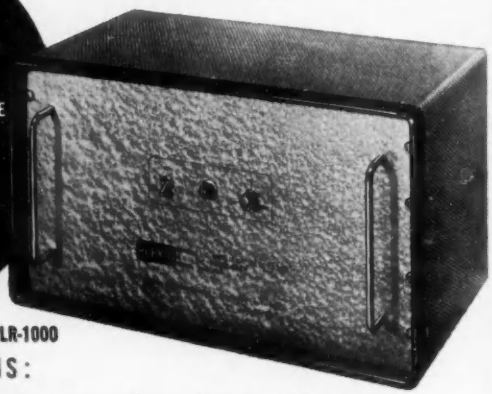
VIBRATING CONTACTS
•
REGULATES RMS VALUE
RACK PANEL OR
CABINET MOUNTING
•
IDEAL FOR
UNATTENDED
INSTALLATIONS



Model MLR-1000

SPECIFICATIONS:

Input voltage range: 95 to 135 volts

Output voltage: Nominal 115 volts, can be adjusted from 110 to 120 v.

Output current: 8.5 amperes

Frequency range: 60 cycles ±10%

Wave form distortion: 3% max.

Power factor range: 0.5 lagging to 0.9 leading

Response time: 0.2 sec.

Maximum load: 1.0 KVA

Ambient temp. range: Up to 45° C

Dimensions: 19½" wide x 11½" high x 11½" deep (Cabinet)
19" wide x 10½" high x 10" deep (rack panel)

Mounting: Cabinet or 19" rack panel

Finish: Gray hammertone

Weight: 85 lbs.

Also available—3 KVA Model MLR-3000, same specifications except: output current 25.5 amps. Dimensions 19" wide, 14¾" deep x 12¼" high (rack) or 19½" wide x 16¼" deep x 12¾" high (cabinet). Weight 170 lbs.

PERKIN PERKIN

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PERKIN ENGINEERING CORPORATION

PERKIN
DC POWER SUPPLIES

Perkin also manufactures a complete line of standard DC power supplies as listed below:

28 VOLT DC POWER SUPPLIES:

Model	Volts	Amps	Reg.	AC Input (60 cps)	Ripple rms
28-5VFM	0-32 V	5	20% (24-32 V range)	115 V 1 phase	2%
28-10WX	24-32 V	10	±½%	100-125 V 1 phase	1%
MR532-15A	2-36 V	15	±½%	105-125 V 1 phase	1%
28-15VFM	0-32 V	15	20% (24-32 V range)	115 V 1 phase	5%
M60V	0-32 V	25	±1%	115 V 1 phase	1%
MR1040-30A	5-40 V	30	±1%	100-130 V 1 phase	1%
28-30WXM	24-32 V	30	±½%	100-125 V 1 phase	1%
28-50WX	24-32 V	50	±½%	230 V* 3 phase	1%
MR2432-100XA	24-32 V	100	±½%	208, 230, 460 V ±10% 3 phase	1%
MR2432-200	24-32 V	200	±½%	230 V* 3 phase	1%
MR2432-300	24-32 V	300	±½%	230 V* 3 phase	1%
MR2432-500	24-32 V	500	±½%	230 V* 3 phase	1%

*±10%. Also available in 460 V ±10% AC input. Will be supplied with 230 V input unless otherwise specified.

6, 12, 115 VOLT DC POWER SUPPLIES:

	Model	Volts	Amps	Reg.	AC Input (60 cps)	Ripple rms
6 Volt	6-5WX	6 ±10%	5	±1%	95-130 V 1 phase	1%
	6-15WX	6 ±10%	15	±1%	95-130 V 1 phase	1%
	6-40WX	6 ±10%	40	±1%	95-130 V 1 phase	1%
12 Volt	12-15WX	12 ±10%	15	±1%	95-130 V 1 phase	1%
115 Volt	115-5WX	115 ±10%	5	±½%	95-130 V 1 phase	1%
	MR13125-5	15-125	5	±1%‡	95-130 V 1 phase	1%‡
	6125-25**	115-125	25	1½-4%	230/460 V 3 phase	5%

**Germanium Rectifier Unit ‡Increases to 2% @ 15 V.

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Control ENGINEERING

JULY 1957 VOL. 4 NO. 7

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS
Published for engineers and technical management men who are responsible for the design and application of instrumentation and automatic control systems.

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Paul Revere's lanterns prove the idea of communication by light to be at least 180 years old, and a search for earlier references would probably carry it back to the dawn of history. The technique of "one if by land and two if by sea" is a form of parallel coding. Serial coding, a single light flashed sequentially like a Navy blinker, is more common in modern systems. But here mechanical shutters rule out the high data transmission rates required by voice or control signals. The technique abstracted on the cover and explained in the article on page 63 represents a technological breakthrough – now light can be modulated at the video frequencies and transmission over many miles is possible.

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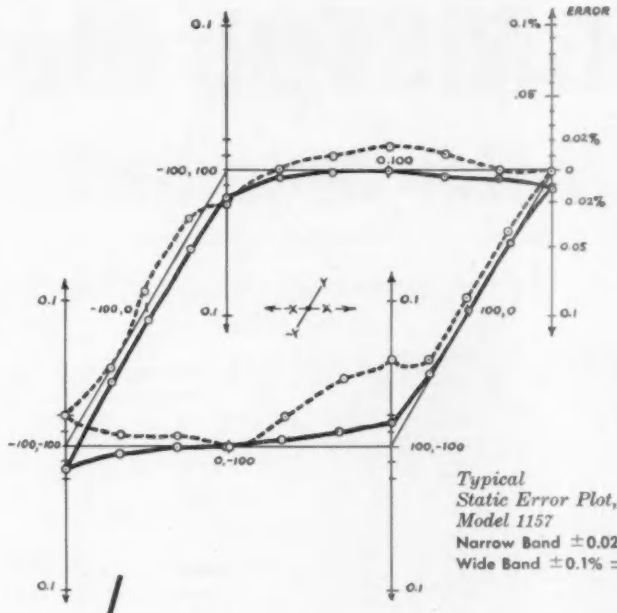
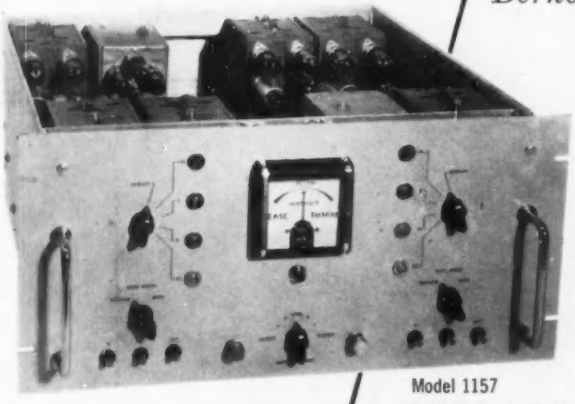
Introducing
Non-Linear Equipment
with
Linear Accuracy



Typical
Static Error Plot,
Model 1157
Narrow Band ±0.025% = ——
Wide Band ±0.1% = - - - -

Beckman® / *Berkeley* EASE®

ELECTRONIC MULTIPLIER



Model 1157
Dual Electronic Multiplier

Beckman/Berkeley's Model 1157 electronic multiplier provides for the first time a unit offering both high accuracy and wide frequency response. It is the most accurate tool available for multiplying two varying voltages in the range of +100 to −100 volts. In addition, the carrier frequency of Model 1157 may be increased, providing greater band width for the output variable.

Another important feature of the new EASE* multiplier is its versatility. By energizing a relay within Model 1157, the unit becomes a divider without the use of any external components. Furthermore, its internal amplifiers may be used as operational amplifiers at the user's discretion, increasing the capacity of existing equipment. These internal amplifiers are chopper stabilized for low drift. Rugged construction, the extensive use of premium components and plug-in modules, including amplifiers and switching circuitry, simplify maintenance and improve reliability.

SPECIFICATIONS

STATIC ACCURACY
NARROW BAND RANGE: Product accurate to better than 0.01% of full scale in any one quadrant (full scale = 200 volts). Product accurate to better than 0.025% of full scale in all four quadrants.
WIDE BAND RANGE: Product accurate to better than 0.05% of full scale in any one quadrant. Product accurate to better than 0.1% of full scale in all four quadrants.

DRIFT
NARROW BAND RANGE: Less than 20MV (0.01% of full scale) over any 6-8 hour period.
WIDE BAND RANGE: Less than 60MV (0.03% of full scale) over any 6-8 hour period.

DIVIDER OPERATION
Provides circuitry for converting each multiplier channel to a divider by energizing a relay from patchboard. Output = 100X/Y; Y negative.

AMPLIFIER USE AS INVERTERS
Patchboard energizing of a relay allows the three Model 1048B Amplifiers per channel to be used as inverters when unit is not being used as a multiplier.

Complete technical specifications on the Model 1157 Dual Electronic Multiplier are available on request. Please address Dept. L7.

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BRISTOL Metagraphic
offer broadest measurement

For temperature, pressure, vacuum, differential pressure, flow,

BRISTOL METAGRAPHIC PNEUMATIC TRANSMITTERS

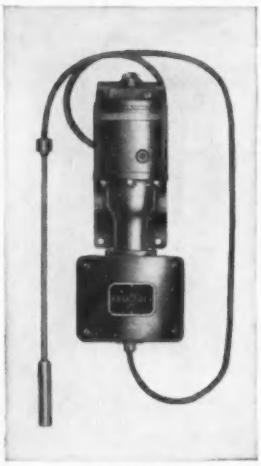
are the measuring centers of the Metagraphic transmission system. They are constructed for friction free operation, and provide superior control and high speed transmission, with low air consumption. Metagraphic transmitters are available for measuring practically any variable encountered in industrial processing.

PRESSURE, VACUUM

Ranges as low as 0 to 3" of water; as high as 0 to 10,000 psi.

COMPOUND PRESSURE AND VACUUM

Ranges from 15" mercury to 0 to 150 psi.



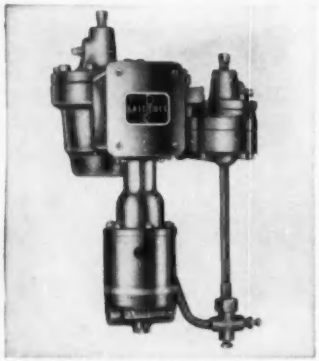
TEMPERATURE

Ranges as low as —100°F, as high as 5000°F.

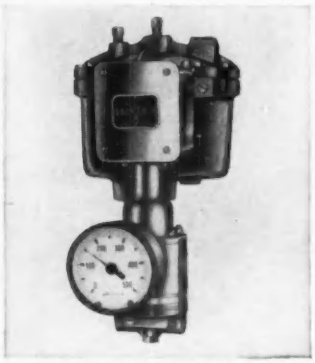
ABSOLUTE PRESSURE

Ranges as low as 0 to 5mm of mercury and up. Available in bronze or stainless steel.

DIFFERENTIAL PRESSURE AND FLOW. Ranges as low as 0 to 1" water and up. Offered in a variety of meter bodies to satisfy almost any requirement or preference, including:



MERCURY MANOMETER



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DRY-TYPE METER BODY

pneumatic transmitters
range and widest coverage

liquid level, and mechanical motion

LIQUID LEVEL

Full range of applications from water and other liquids in tanks, open and closed vessels of all kinds; weirs, canals and reservoirs—pressure and bubbler types—for corrosive conditions and solid-bearing liquids.

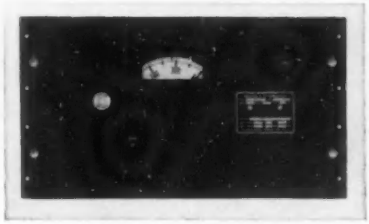
MECHANICAL MOTION

For measuring and transmitting any mechanical motion such as float motion, gate position, or valve stem action, as well as others.

Indicators can be furnished on all transmitters.

MEASURE ELECTRONICALLY, TRANSMIT PNEUMATICALLY

with Dynamaster Electronic Potentiometer Transmitter. Input signal may be a voltage, current or change in resistance, capacitance, or inductance. Output is a pneumatic signal proportional to measurement. Ideal for pH, speed, viscosity, density, strain, force, dew point and other measurements requiring electronic transducer.



Measure almost any variable, transmit universal 3-15 psi* pneumatic signal to a recording receiver or controller

Get the widest variety of pneumatic transmitters on the market in the Bristol 650 Metagraphic line.

They offer you more models and a variety of lower ranges, higher ranges and easily adjustable partial ranges that no other line of pneumatic transmitters can match. Check these Metagraphic advantages:

Easy maintenance. Spare parts are cut to a minimum with the Metagraphic transmitter. The reason: all transmitters are basically the same; only the measuring elements and their housings differ.

Uses standard Bristol measuring elements. The same standard, highly developed and proven Bristol measuring elements that are used in Bristol recording and controlling instruments are used in the Metagraphic transmitter. They are the result of 68 years of research and experience in building hundreds of thousands of instruments for practically every application, and incorporate the latest engineering developments in the field. These high-torque measuring elements, with wide-angle travel, give powerful, positive operation.

Rugged, weatherproof. Bristol Metagraphic transmitters are extremely rugged. They are weatherproof and can be installed anywhere.

Range easily adjustable. The locations of partial ranges are easily adjustable through wide range limits on most transmitters. The span of a given transmitter can also be changed without difficulty. It is therefore no longer necessary to know and specify the exact range in advance, when ordering transmitters.

Thousands of Bristol Metagraphic transmitters are already in operation, giving reliable, trouble-free service. Find out how their advanced design can simplify your measurement, recording, and control problems. Write the Bristol Company, 101 Bristol Road, Waterbury 20, Conn. 6.83

**Other transmitting pressures also available.*

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TRAIL-BLAZERS IN PROCESS AUTOMATION

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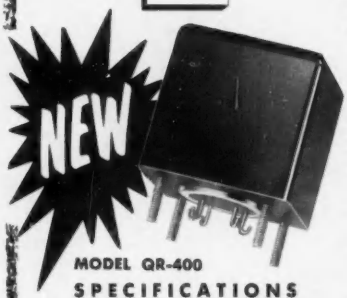


MODEL QR-400
SPECIFICATIONS

- Quadrature attenuation: 40 db min
- In-phase attenuation: 6 db max
- Maximum signal: 8 volts rms
- Maximum noise: 10 millivolts rms
- Circuit: interstage of either electron tube or transistor voltage amplifier
- Temperature range: −55 to +100 Centigrade
- Dimensions: 1½" x 1½" x 1½"
- Package: potted in epoxy resin hermetically sealed in metal case

Also Model QR-60 for 60 cps applications

For complete specifications, write for
TECHNICAL BULLETIN **1557**

FEEDBACK CONTROLS
INCORPORATED

Dept. CE
899 Main Street
Waltham 54, Mass.

SHOPTALK

Digits draw to a close

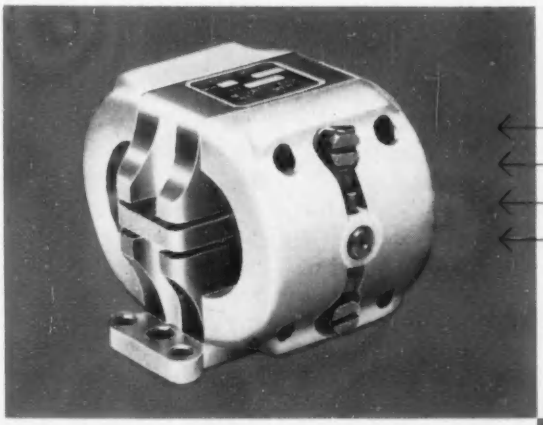
This month's digital application article ("How Input/Output Units Affect Computer Performance", p. 97) is the next to the last in the two digital series conceived three months after we started publishing in 1954. Since publication of the first article in October, 1955, 13 basic digital articles have flowed under the bridge, covering all aspects of the operating principles and hardware of digital equipment. And next month the 14th digital application article—covering digital telemetering—will complete the series dealing with the application, system design, programming and commercial availability of digital equipment in the three major areas of scientific computation, business-data processing, and process control. A total of 197 pages, roughly equivalent to a 600-page book, has been devoted to these series.

But it's really only the beginning

When the decision to organize these series was made in November 1954, it was agreed that a minimum should be observed in covering a field of such tremendous future importance to our readers. The series permitted us to give you this minimum in an integrated and complete manner. And from the way things look now, it's a good thing we did. The use of digital techniques and equipment in control system simulation and design, in business-data processing, in production-data recording, in automatic data logging, in test-data processing, in programming of machine tools and steel mills, and in the control of processes is on a sky-rocketing transient. From the "minimum" baseline our coverage will go up and up, paralleling or even preceding the penetration of digital techniques into the field of automatic control.

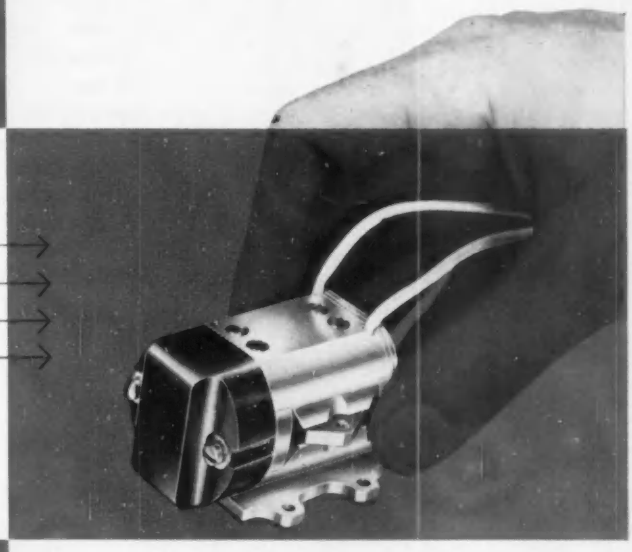
Packaging the minimum

The intense interest in the digital series has solidified into a big demand for reprints. For this reason, CONTROL ENGINEERING will reprint the entire Digital Application Series in one package, to be available about October 1, 1957, at a single-copy price of $3.00. Prices for multiple copies can be obtained by contacting Mrs. Florence Baxley, Readers Service Dept., CONTROL ENGINEERING. Advance orders will be accepted (and, in fact, welcomed, since they will give us an idea of the size of the demand). The Basic Digital Series will be available as a book from the McGraw-Hill Book Co. sometime late next year. For those who want to fill in an incomplete set of either series, copies of the individual articles can still be obtained at a cost of 25¢ each.



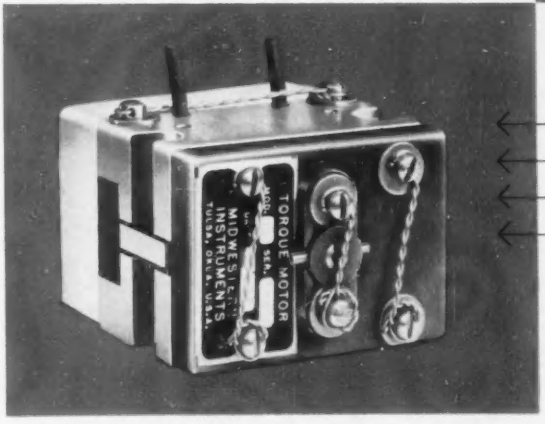
MODEL 9

RATED MAXIMUM CURRENT	40 ma
NATURAL FREQUENCY	425 cps
LINEAR STROKE	0.015 in. (with 20 ma input)
WEIGHT	21 ozs.
OUTPUT FORCE	7.5 lbs. (with 40 ma input)



MODEL 10-D

RATED MAXIMUM CURRENT	40 ma
NATURAL FREQUENCY	600 cps
LINEAR STROKE	0.008 in. (with 20 ma input)
WEIGHT	9.5 ozs.
OUTPUT FORCE	5.00 lbs. (with 40 ma input)



MODEL 11

RATED MAXIMUM CURRENT	40 ma
NATURAL FREQUENCY	300 cps
LINEAR STROKE	0.008 in. (with 20 ma input)
WEIGHT	14 ozs.
OUTPUT FORCE	4.5 lbs. (with 40 ma input)

These high-performance electro-mechanical tranducers are being utilized in hundreds of applications where a few watts of power are used to control linearly forces up to 8 pounds. . . . their completely impregnated and incapsulated coils allow usage in high humidities or immersion in hydrocarbons. Additional information for adapting these torque motors to specific requirements available on request.

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TORQUE MOTORS

for actuation and transducing

MIDWESTERN INSTRUMENTS
41ST AND SHERIDAN / TULSA, OKLAHOMA

Statham liquid rotor angular accelerometers are rugged and reliable. They may be ordered with either an unbonded strain gage or inductive pickoff and are available in ranges from ±1.5 to ±3,000 rad/sec².

Please request our Accelerometer Catalog and Instrument Notes No. 26 "Some Design Considerations For Liquid Rotor Angular Accelerometers"

Statham
LABORATORIES
LOS ANGELES 64, CALIFORNIA

FEEDBACK

PROBLEM FORUM

Test facilities for evaluating the performance of materials, control systems, and structures under conditions simulating re-entry into the atmosphere play an increasingly important role in the development of missiles. Complex measuring, recording, and control equipment automatically programs and coordinates the transient application of loads, vibration, and heat. These automatic tests have created needs for new measuring elements. One of these needs is expressed by a reader at Boeing Airplane Co.

If you can suggest a measuring element which meets his requirements, send complete application information to the editor of this magazine for forwarding. We will pay an award for information we publish. And don't forget to submit your own measurement and control problems—they may win awards, too.

TO THE EDITOR—

We need a probe to sense radiant heat flux emanating from T-3 quartz lamps whose tungsten filaments are operated from 2,500 to 3,250 deg K. The probe should sense small changes in a varying heat flux and correctly indicate steady state intensity levels. The following are required:

(1) range: up to 100 Btu/ft²/sec
(2) weight, less handle: less than 0.3 lb
(3) solid angle sensitivity: 75 deg from the normal to the sensitive surface
(4) speed of response: 90 percent of full scale in 25 millisec
(5) accuracy: better than 0.5 Btu/ft²/sec
(6) sensitivity: 0.2 Btu/ft²/sec
(7) repeatability: equal to sensitivity
(8) stability with time: 2 Btu/ft²/sec/hr
(9) output: dc millivoltage sufficient to operate a strip-chart recorder

Jack W. Powell
Seattle, Wash.

Is controls manufacturing an industry?

TO THE EDITOR—

We are interested in automatic controls used in processing and manufacturing operations and whether their manufacture may be considered as a subindustry group within the framework of electronics. If the manufacture of automatic-control equipment can be so classified, has this "industry" ever been the subject of a study either by your organization or some other source? Specifically, we are interested in the historical development, the present status, and the expected growth of the automatic-control business along with any quantitative data we may be able to obtain.

Richard G. Fourman
A gas pipeline company
Shreveport, La.

The manufacture of automatic controls for processing and manufacturing operations is most definitely an industry, but it is not a subindustry within the framework of electronics. Sources of data:

1. **"Instrument Sales Treble in Seven Years", CtE, July '56, pp. 61-65.**
2. **"Instrument Census Exceeds Expectations", pages 16 and 17 of the same issue.**
3. **1954 Census of Manufacturers, U. S. Bureau of the Census, from which much of the data for items 1 and 2 was extracted. The Standard Industrial Classification used by the bureau hides what you seek under "scientific instruments", "mechanical instruments", and "surveying instruments".**
4. **"Control Engineer Profile", "Process Control Instruments", and "Survey of Test Equipment", three reader-research reports available from our editorial offices.**
5. **Testimony of witnesses at Dec. 12,**

NO ROOM FOR CROSS-TALK ERROR?

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Low cross-talk, high sensitivity, and small size are combined by Giannini in this newest family of axial accelerometers. Covering the ranges of ±1g to ±40g, three standard hermetically sealed models offer a wide variation of potentiometer resistances, natural frequencies and resolution.

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For a ready solution to critical acceleration instrumentation, call or write Giannini, the largest producer of precision telemetering and control transducers in the world.

SPECIFICATIONS

RANGES: ±1g to ±40g
RESISTANCES: 2000 ohms to 10,000 ohms
RESOLUTION: 0.25% to 0.5%
NATURAL FREQUENCY: 2.8 cps to 54 cps
THRESHOLD SENSITIVITY: 0.02g to 0.04g
CROSS-TALK ERROR: 0.01g/g

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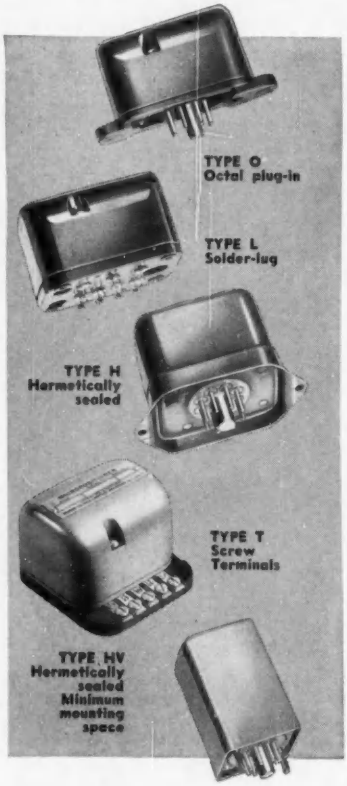
THE MARK OF QUALITY
BARBER COLMAN

ultra-sensitive relays

help solve control problems in wide range of industrial applications



Operating on input powers of 40 to 1000 microwatts, the Barber-Colman Micropositioner is ideal for use as a null detector in resistance bridge circuits, a differential relay in electronic plate circuits, and an amplifier in photo-electric circuits. Standard contact arrangement is SPDT, null seeking. Can be operated in excess of 100 cps. This ultra-sensitive polarized d-c relay has been widely used in many control applications . . . in nucleonics, communications, instrumentation, process control, railway signal transmission, and aircraft temperature control and remote positioning. Write for free copy of Bulletin F 3961.

BARBER-COLMAN COMPANY
Dept. S, 1848 Rock Street, Rockford, Illinois

FEEDBACK

13, and 14 (1956) hearing of Rep. Wright Patman's Economic Stabilization Subcommittee. Ed.

Control Personality prompts inquiry

TO THE EDITOR—

I have been reading an old copy of CONTROL ENGINEERING, February, 1956, to be precise.

On page 15 there is a reference to a theoretical calculation of corrugated diaphragm performance by Bill Wildhack. I should very much like to obtain further details on this investigation and would be grateful if you would let me know whether it is possible to obtain a report of this work.

G. A. Williams
Rheostatic Co., Ltd.
Slough Bucks, England

We suggest that you contact Mr. Wildhack, Chief, Office of Basic Instrumentation, National Bureau of Standards, Washington, D. C. Ed.

Prior claim?

DEAR MR. CHUBBUCK—

Your article, "Are High Performance and Low Cost Compatible in Hydraulic Servos?", March, '57 issue of CONTROL ENGINEERING was very interesting. I worked on the development of a similar valve called a time-modulated two-stage hydraulic valve (patent number 2,655,940) while at North American Aviation in 1950. This valve was used successfully in a missile autopilot servo. However, due to the security classification of the program, no public disclosure was made at the time.

You may be interested to know that the production of this valve by NAA was dropped because of its high production cost, in favor of a commercially available valve developed a few years later.

Kenneth R. Jackson, President
Dynalysis Development Laboratories
Los Angeles, Calif.

Seems ironic that publication of Mr. Jackson's work in 1950 might have eliminated the need for much of Chubbuck's development. Looks as though military security caused duplication of development. Of course this could mean some independent improvements by both development groups, but the overall result was that the American taxpayer paid twice. Ed.

A common minority

TO THE EDITOR—

We note with interest the report in CONTROL ENGINEERING (April 1957, p. 127) on the plugboard-programming of freight-car switching at Ange, Sweden. We are happy to see recognition of progressive railroading any place in the world, including, of course, the United States. Too many nonrailroad people seem to feel that nothing new has been done on the railroads since the Civil War.

Incidentally, as manufacturers of *electrically* operated car retarders, we were somewhat chagrined to read in your caption for Figure B that "American makes are commonly pneumatic". Actually, of the extensive footage of car retarders installed on this continent since the war, just over half has been of our electrically operated type, rather than of the competitive pneumatic variety.

H. E. Downey
General Railway Signal Co.,
Rochester, N. Y.

Americans do it, too. See "Automatic Freightyard Switches Cars Quickly Yet Gently", page 28, January, '55, CtE. Ed.

Japanese digits itch for AIA report

TO THE EDITOR—

I am a Japanese government employee practicing control engineering, especially as it applies to numerically controlled machine tools. My work involves designing sampled-data servomechanisms, computer and control logic, and delay lines synthesized with the Parametron, which uses the parametric oscillation caused by the nonlinearity of ferrite cores.

On page 194 of Abstracts in the February issue I read with great interest "Numerical Control—Air View", from "Numerical Control of Machine Tools", a report sponsored by the AIA-AMEC-Numerical Control Subcommittee, and prepared by C. B. Perry and B. Gaiennie.

How can I obtain a copy?

K. Togino
Government Mechanical Laboratory
Tokyo, Japan

Write Miss Catherine Prentice, Aircraft Industries Association of America, Shoreham Building, Washington 5, D. C. AIA has released to the industrial press a summary of the Perry-Gaiennie report. The summary report is available; Miss Prentice will indicate whether the full report can be obtained. Ed.

In February, this column carried a SAMA study of manufacturers' preferences for standards in ac and dc

measurement and control transmission signals. Shortly afterward Fielden Instrument's Ralph Coles replied to a query on this same subject from T. P. Gray of Imperial Chemical Industries in London. To shed more light on the problem of selecting a standard electrical transmission for control loops, we repeat here portions of Coles' letter and enclosure. Ed.

T. P. GRAY—

At the present time no standards have been set for electrical signal transmission as has been done in the case of pneumatic control signals, where the 3-15-psi standard is now universal. Our choice of a 3-15-ma dc signal [in our pneumatic-electric-pneumatic system] was based on a careful study of all the factors involved, which led us to the conclusion that the 3-15-ma standard was the best compromise. Our analysis of the various factors affecting the choice of signal values in a dc system is enclosed.

(The following is taken from the enclosure. Ed.)

1. The system should be intrinsically safe. This means no contacts, minimum inductance, available energy less than 1/100th of that required to ignite the most combustible mixture of methane and air at ambient temperatures and pressures. It also means that at least three simultaneous faults must occur before the system becomes unsafe.

2. The signal-generating supply should have a power-handling capacity of at least 100 percent safety margin. For vacuum-tube systems, tubes should be used that do not require excessive input and heater currents. Tube combinations and transistors supply about 40 to 50 ma dc without excessive heating. With a 100 percent safety factor, then, the maximum signal should not exceed 20 ma. Note: the PEP system itself uses neither tubes nor transistors and its current-handling capacity is extremely flexible, but its compatibility with systems designed around these elements appeared necessary.

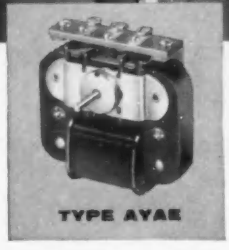
3. All users are familiar with the 3-to-15-psi signals used in pneumatic systems, and this 5-to-1 range of max to min signals is consistent with results shown in the SAMA study on electrical signals. Since hybrids of pneumatic and electrical systems will be used for many years to come, a one-to-one conversion of electric-to-pneumatic and pneumatic-to-electric signals simplifies matters. By adopting 3-15-ma dc, a double conversion is avoided.

4. [Coles discusses this fourth point in great detail; only the essence is stated here. Ed.] A portion of the dc current entering a transmission line will not reach the receiving end due

THE MARK OF QUALITY

BARBER COLMAN

Small Motors



TYPE AYAE

"We needed compact reversible motors to drive TV camera iris and focus mechanisms."

R. A. White, Mechanical Development Department
General Precision Laboratory Incorporated
Pleasantville, New York

The GPL Remote Iris and Focus Television Camera shown above may be operated as far as 500 feet from control location — with complete remote control of lens optical focus and iris aperture. Vernier control of focus is provided regardless of lens focal length. For this camera, General Precision Laboratory selected two Barber-Colman AYAE reversible small motors . . . one drives the lens focus mechanism and the other drives the iris control. "Plus" features of this high-torque, fast-reversing Barber-Colman motor include low-inertia rotors for quick, positive start, rapid reverse . . . porous bronze bearings . . . hardened and ground stainless steel rotor shafts . . . rugged construction . . . long life. If you have a design problem involving small motors, let Barber-Colman Company engineers help you solve it with the exact motor for the job.

FREE HELPFUL DATA SERVICE on the complete line of Barber-Colman small motors which includes unidirectional, synchronous, and reversible motors up to 1/20 hp. With and without reduction gearing — open or enclosed types. Expert engineering service available. Write today, outline your problem, ask for free data sheets and Catalog F-4271, or see Sweet's Product Design File.

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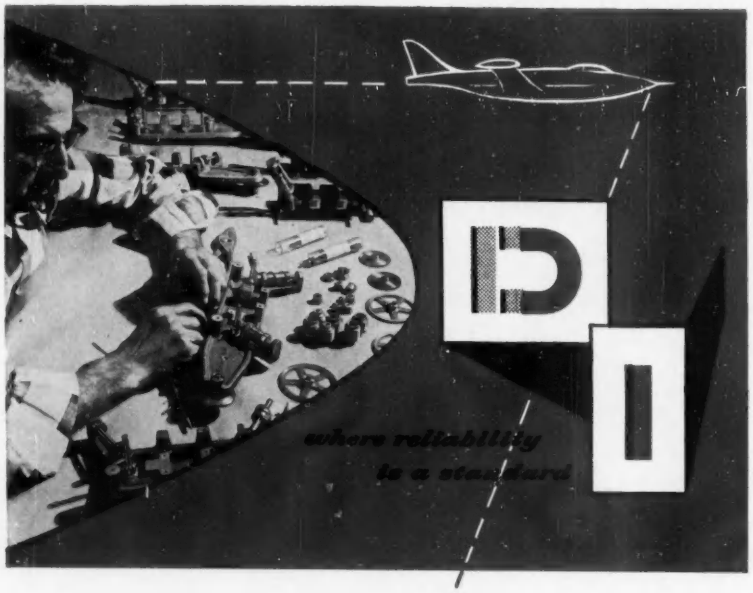

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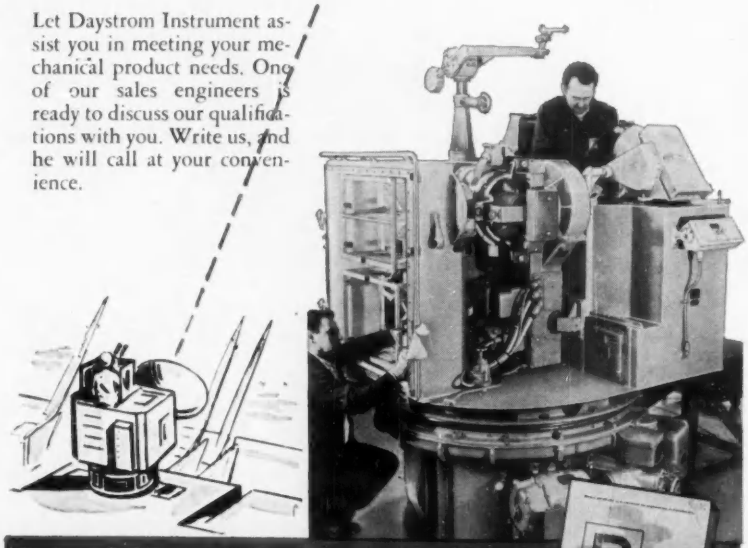

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DAYSTROM INSTRUMENT

Archbald, Pennsylvania

Division of Daystrom Inc.

FEEDBACK

to leakage current. This is an error that increases not only with line length but also with the load resistance. Reduced load resistance in a [force balanced] receiver can be obtained by increasing the wire diameter; for a given supply voltage, this reduces error inversely proportional to the square of the maximum current in any range. Therefore, the supply voltage is inversely proportional to the maximum current in any range. In a practical transmission line, with about 0.5 megohms/mile shunt resistance, these technical considerations indicate a design range between 2 to 20 ma. Since it was previously shown that the max current should not exceed 20 ma, a range of 3-15 ma is an ideal compromise.

Information please—on sonic testing

To the Editor—

In the February issue of Control Engineering under *Ideas at Work* is an interesting article entitled "Testing Hardness Automatically". In this article, Mr. E. A. Rave discusses automating the usual Rockwell hardness test system, certainly proven by past performance.

In recent years, a system of what I like to call "sonic testing" has been used by at least one large manufacturer that I know of. This system consists roughly of striking the test piece with another object and relating the frequency of the audible "ring" to that "ring" given off by an object of known hardness under the same conditions. This system, it appears to me, would lend itself to automation with a minimum of complications. However, I have seen only one application of this system, and it appeared to have a lot to be desired.

Do you know of any applications of this principle being used today—or of any work being done along these lines?

B. J. Vachon
North Hanover, Mass.

We checked with Mr. E. A. Rave, author of the Idea at Work which caught your eye. He replies, "We do not have any information concerning 'sonic testing' for hardness value of materials or any method employing this principle. We in turn would like to receive any information that becomes available concerning this type of hardness testing."

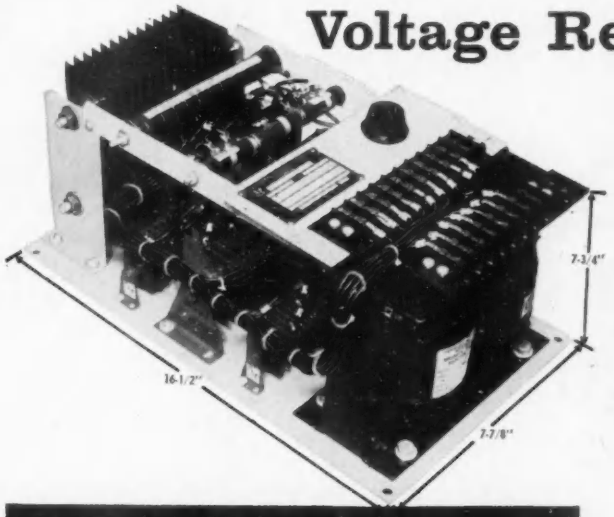
Looks like we drew a blank. That leaves the question up to you, the reader. If you know the answer, send it in. Ed.

Now! A Low-Priced Completely Static Voltage Regulator

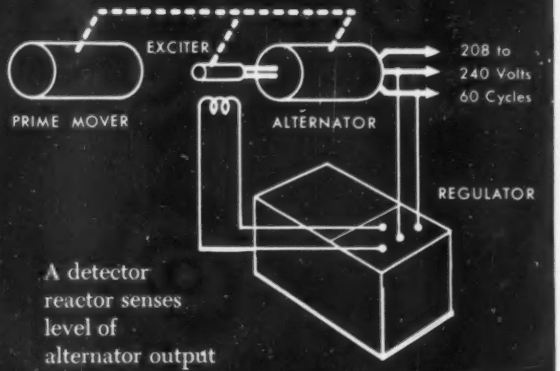
by

VICKERS*

For Fast, Accurate Voltage Regulation of 60-Cycle Alternators



How the Vickers Static Voltage Regulator Works



A detector reactor senses level of alternator output voltage and supplies a control signal to the magnetic amplifier stage. The amplifier in turn maintains alternator output voltage constant by supplying controlled excitation to the exciter. A regulator control knob permits adjustment of alternator voltage.

This new unit is ideal for applications where a simple and inexpensive but rugged voltage regulator is desired. The Vickers regulator is a single-stage magnetic amplifier unit utilizing selenium rectifiers and wire wound resistors. It is completely static, with no moving parts, and is thus not affected by vibration. Other features:

- Works into 20 to 100 ohm exciter field resistance without adjustment.
- Supplies exciter field current within a range of 0.15 to 1.35 amperes.
- Connects directly to 208 to 240 alternator without need of a potential transformer. Operates with alternators having any output voltage when used with a 500 VA potential transformer.
- Adjustable line drop or reactive current compensation provides zero droop at a given load when a Vickers accessory current transformer is used.
- Extremely simple to install, with only 6 terminal connections.

* Trade Mark

Write Today for Complete Information, Including New Brochure, on the Vickers Static Voltage Regulator.

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Differential Pressure Cell Transmitters

Complete line includes air-operated and electric-operated d/p Cell Transmitters covering ranges from 0-20" to 0-800" of water; working pressures up to 1500 psi.

Type 13A d/p Cell Transmitter

- Positive Overrange Protection—up to full 1500 lb. rating
- Fully Adjustable Ranges—0-20" to 0-250" water
- Automatic Internal Damping — fast, stable measurement
- Simplicity—easiest, lowest-cost installation, lowest maintenance

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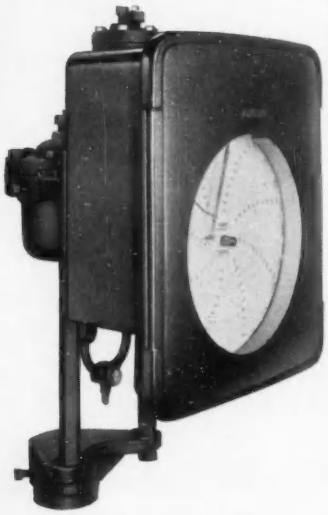
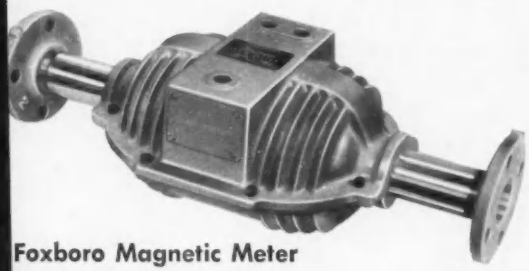
Complete line includes mercury types covering ranges from 2 to 400" of water; working pressures up to 5000 psi.



Type 28 Mercury Meter

- Permanent Full-Scale Meter Accuracy — exclusive segmental lever design provides linear transmission from float to pen
- Highest-Powered Pen Drive — large float with long travel
- Minimum Ambient Temperature Effects — float located in high pressure chamber

PROBLEM



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Measures Fluid Velocity Directly

Adds No Pressure Drop

Uniform Flow Scale

Overall Accuracy Better than 1% of Range Over Entire Scale

Full Accuracy Sustained Even on Liquids Other Meters Can't Handle — even sand and water slurries

THERE ARE two logical reasons why Foxboro Instrumentation assures you *optimum* results in measurement or control of process fluid streams. First; Foxboro offers the widest variety of measuring and controlling devices . . . the *right* equipment for every application. For example, only Foxboro offers all these basic meter types: differential pressure cell flow transmitters, magnetic meters, mercury meters, and weir meters. Second; Foxboro provides 45 years of engineering experience in every phase of fluid mechanics. From the simplest general utility-type instrument to complex automatic ratio control systems, you get highest accuracy, efficiency, and economy. Whenever you have a flow problem involving liquids, vapors, gases, or slurries — in pipes, ducts, or channels, you can solve it best by specifying Foxboro. Only a few instruments are described on these pages. For full details; or for specific information on *your* problem, contact your nearby Foxboro Field Engineer, or write **The Foxboro Company, 367 Norfolk St., Foxboro, Mass.**

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Float-and-Cable Type Meters

- Rigid Construction — weather-tight case; all working parts of corrosion-resistant materials
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Electric or Pneumatic Type Rotameters

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All Primary Elements, Valves, and Accessories required for assembly of complete flow measurement and control systems

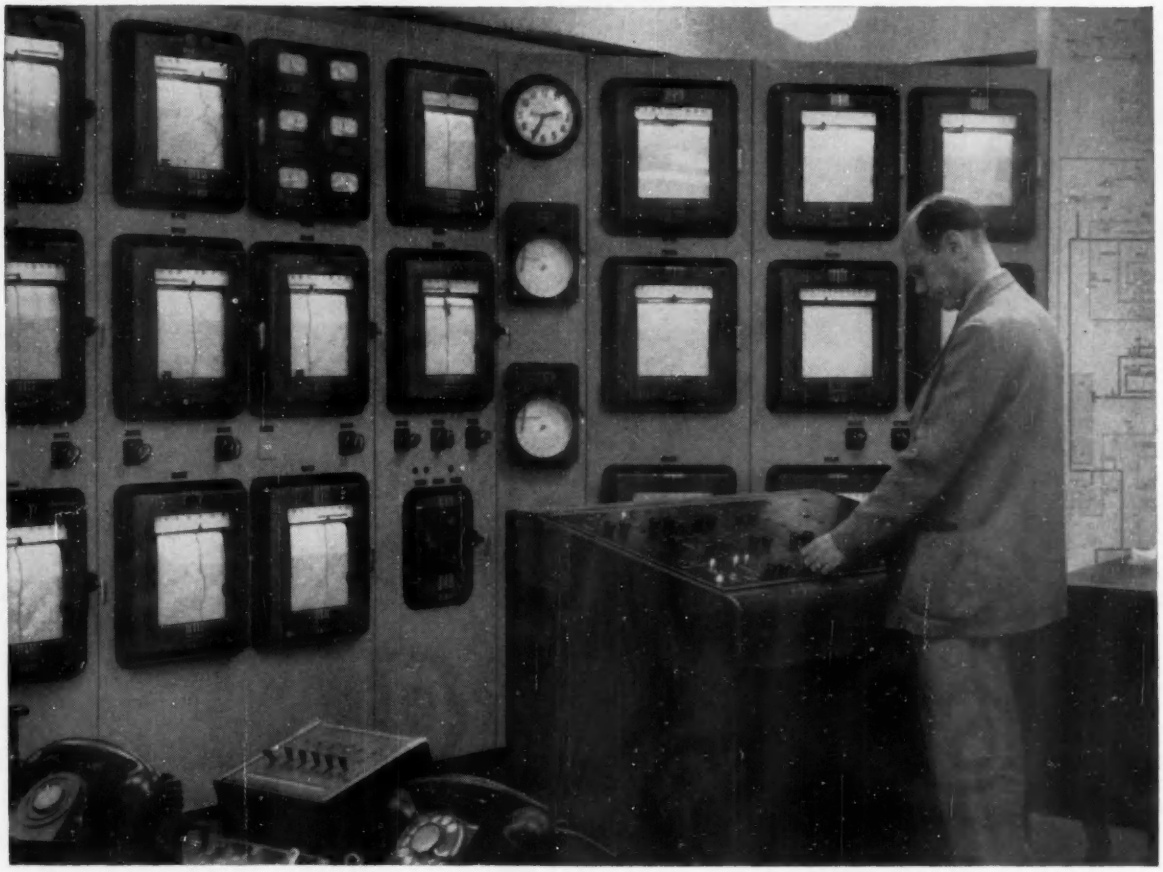


Photo courtesy Public Service Co. of Oklahoma

He's Using an "Idea Amplifier" to solve a cost-cutting problem

This Load Dispatcher's aim at the moment is to coordinate regulation of hydro and steam generation. On paper at least, this coordination contributes to lowest-cost operation, but in actual practice, its execution involves numerous factors —many of them variables, and far too complex to be calculated manually in a hurry.

So the Dispatcher turns to electronics for amplification and execution of his idea. He uses the console in front of him to convert it to an electrical equivalent which is instantly calculated and telemetered in the form of control pulses to any given number of turbine governor motors simultaneously . . . and it's all done with cost-cutting accuracy beyond the ability of even the best manual operation.

The "amplifier" in this case is an Area Load Control console—a device with computing circuits that functions as the brain of each Leeds & Northrup Area Load Control system. Already, these custom-engineered systems are installed on utility networks accounting for nearly a *third* of American generation.

Operating flexibility of Area Load Control is one reason for this preference. For when day-to-day operating conditions change (due to wet coal, loss of a cooling fan, unscheduled maintenance, etc.) Area Load Control provides the Load Dispatcher with the necessary flexibility to meet these problems as they arise.

Next time you have an opportunity, talk with your power neighbors who use Area Control—get the benefit of their thinking plus the ideas of your own operating staff. It's a method for turning in cost-cutting recommendations that work.

JOHN L. BARNES **eyes the moon**

"By 1970, man will be able to circle the moon in a space vehicle and then return to earth safely!"

That sounds like a quote from a science-fiction novel, but it's not; it's the considered opinion of John L. Barnes, 50-year-old mathematician-engineer president of Systems Laboratories Corp., a California company that's hard at work today trying to make the trip to the moon possible. Barnes first became interested in the prospects for interplanetary travel while he was chief of guidance at North American Aviation's Aerophysical Laboratory, working on aircraft fire control systems and the Navaho missile. Investigations for a guidance and control system for the Navaho convinced Barnes that the breakthroughs to space travel had been made. He's been excited about the prospect ever since.

Barnes' determination to reach the moon—and his role as president of SLC—are a far cry from the academic way his career started. With SB and SM degrees in electrical engineering from MIT, he went to Princeton University to sharpen his math background. By 1934, he had earned AM and PhD degrees in mathematics and had acquired a bride, courted while she was attending the Institute for Advanced Studies at Princeton. For the next seven years, until World War II, Barnes taught at MIT and at Tufts. The war brought him his first full-time contacts with industry.

Just before he left Tufts, he coauthored—with Murray F. Gardner—the textbook, *Transients in Linear Systems*. The book caused a mild sensation in engineering circles because it pioneered the treatment of servo systems by the Laplace transformation. The text has sold more than 27,000 copies.

From North American Aviation Barnes went to Ramo-Wooldridge as a consultant on the ICBM program, then to Lockheed's Missile Systems Div., where his ideas about space travel became strong convictions, and then to the vice-presidency of Systems Research Corp., organized by scientists who resigned from Lockheed in 1955. When SRC decided to join the Ford Motor Co. as a subsidiary, Barnes left to organize his own company with several similarly inclined associates, including Dr. Richard De Lano—codesigner of the Falcon missile.

Despite the fact that many still look askance when they hear talk about trips to the moon, Barnes has managed to keep SLC—the first organization specifically established to design basic systems for interplanetary travel—operating in the black. He does it with subcontracts from prime missile-systems designers. Typical projects (Barnes insists work must fit into the region of preliminary research for interplanetary space travel or instrumentation and test of projected space vehicles): 1) how to transmit radio waves through the ionized gases of the outer atmospheres; 2) how to use hydrogen or helium as the thrust medium in nuclear rocket engines; and 3) how to slow down a missile for reentry into the earth's atmosphere. According to Barnes, propulsion is the toughest problem blocking manned space travel.

Barnes maintains enough outside activities to keep almost anyone else busy full time. He still teaches at UCLA—in 1948, he set up and taught there one of the nation's first college courses in digital and analog computing; he is active in society doings—he chairmanned the successful 1957 Western Joint Computer Conference; and he's planning a house in Los Angeles' Bel Air Highlands whose swimming pool will be used in an integrated air-conditioning system and as a fire-control reservoir.

In 1955 Barnes flew to Equatorial Africa to combine his hobby of target shooting with his passion for space travel: while searching for potential lunar launching sites, he bagged a full quota of big game. Next summer he'll do some more site-searching—this time in South America. But the trip that still holds the most fascination for John Barnes is that first one to the moon.

MICRO SWITCH Precision

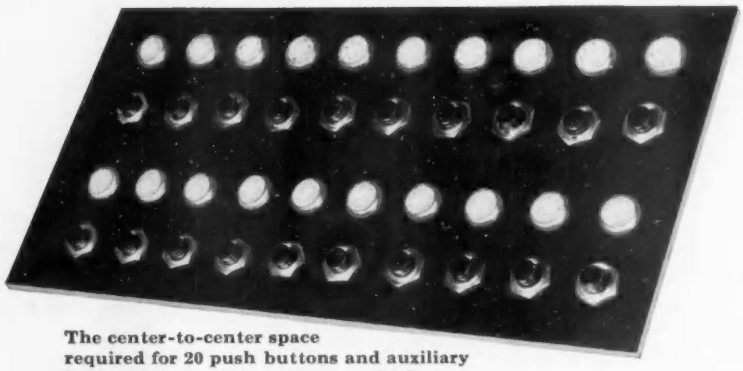
...FIRST IN PRECISION SWITCHING

Here is WHY you can

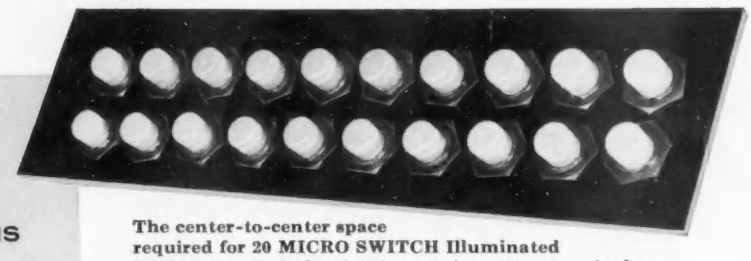
CUT PANEL SPACE **50%**

with MICRO SWITCH Illuminated Pushbutton Switches

Study this illustration... it shows how you can install a given number of MICRO SWITCH Pushbutton Switches—with illumination integral with the button in one-half the panel area necessary when push buttons requiring auxiliary on-and-off lights are used.



The center-to-center space required for 20 push buttons and auxiliary lights is 4 in. x 10 in.—40 square inches.



The center-to-center space required for 20 MICRO SWITCH Illuminated Pushbutton Switches is 2 in. x 10 in.—20 square inches.

FOUR SHAPES OF PUSHBUTTONS AVAILABLE IN FIVE DIFFERENT COLORS

These four translucent button styles are available for MICRO SWITCH Type 52 PB switches.

From the top they include (1) ¾ in. round; (2) ⅝ in. hexagonal; (3) ½ in. round; and (4) ¾ in. square.

They are available in red, yellow, green, blue and white.

(Send for Data Sheet #117)

The savings in space, in time; the difference in operating ease and surety—all commend the use of MICRO SWITCH Illuminated Pushbutton Switches instead of combinations of switch and separate auxiliary on-and-off signal lights.

Here are four NEW MICRO SWITCH Illuminated Pushbutton Switches with many unique and specific features, detailed for you on the opposite page.

In addition to their other features, these switches are obtainable with any one of four different shaped buttons, in five different colors.

Read the specific details of each as set forth on the opposite page. If this information is insufficient for your purpose, ask for Data Sheets by numbers as shown on opposite page.

WHAT'S NEW

Switches have uses unlimited

#52PB7-T2

NEW!

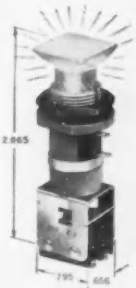
MICRO SWITCH Turn-to-Lock-Down Lighted Pushbutton Switch

This MICRO SWITCH lighted pushbutton switch is a dual-purpose switch. Pushed straight down, it functions as a conventional momentary pushbutton. A push and clockwise twist of the finger tip holds the switch in the operated position. A counter-clockwise twist returns the switch to the unoperated position. The low operating torque required permits the switch to be mounted flush or underflush on a panel without impairing ease of operation . . . This versatile switch can take the place of conventional push button, holding relays and separate indicator lights in many applications. Or it can take the place of an alternate-action pushbutton and provide optional momentary action.

CHARACTERISTICS: Operating force 34 oz. max. Pretravel .220 in. min. Overtravel .120 in. max. Two subminiature switches are SPDT.

(Send for Data Sheet #116)

NEW!



#52PB51-T2

MICRO SWITCH "Space Saver" Lighted Pushbutton Switch —only 2 in. max. below Panel

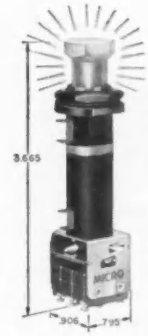
This MICRO SWITCH lighted pushbutton switch is invaluable in applications where space is at a premium. The switch has no pretravel spring mechanism which permits length to be reduced to 2.35 in. (less button). Only 2 in. max. required below mounting panel . . . This switch has a very definite snap-action "feel" and comparative high-force characteristics. Switch body contains a removable subminiature socket for the indicator lamp. Lamps are available for 6, 12 and 28 volts.

CHARACTERISTICS: Operating force—32 oz. max. Pretravel—.070 in. max. Total travel—.110 in. max. Two subminiature switches are SPDT.

(Send for Data Sheet #123)

ELECTRICAL DATA

The subminiature basic switching units used in these four assemblies have SPDT contact arrangement. Contact break distance is .010 in. min. Underwriters' Laboratories list the switches at 5 amps. 125 vac. 30 vdc ratings are: Inductive 3 amps.—sea level, 2.5 amps. —50,000 ft. Maximum inrush rating: 15 amps. 125 or 250 vac and 30 vdc.



#53PB8-T2

NEW!

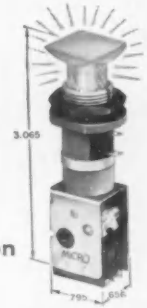
MICRO SWITCH Magnetic Hold-in Lighted Pushbutton Provides Three Functions

MICRO SWITCH lighted pushbutton switch combines the functions of a three-pole double-throw pushbutton switch, indicating light, and holding relay into one compact unit which panel mounts on one-inch centers, both horizontally and vertically. Thus, the cost, wiring, maintenance and added space of these separate components are eliminated . . . A 28-volt dc solenoid is incorporated into the switch shaft. After the button is manually operated, the solenoid holds the switches in the operated position until electrically released. This feature gives the designer complete freedom in panel layout by eliminating the restrictions found in conventional mechanical release designs.

CHARACTERISTICS: Operating force—35 oz. max. Pretravel—.050 in. approx. Total travel—.090 in. max. Three subminiature switches are SPDT.

(Send for Data Sheet #128)

NEW!



#52PB61-T2

MICRO SWITCH Alternate Action Lighted Pushbutton Switch— for Multiple Circuit Control

This MICRO SWITCH lighted pushbutton switch provides on-off control of up to four circuits. With each push of the button, both basic switches are alternated between actuated and unactuated maintained positions, thus providing double-pole double-throw action. Every two pushes of the button completes a cycle of operation. Variations in the long-life nylon index cam are possible which will permit a number of other sequences.

CHARACTERISTICS: Operating force—40 oz. max. Total travel—.100 in. max. Two subminiature switches are SPDT.

(Send for Data Sheet #124)

MICRO SWITCH

A DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR COMPANY

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Here's What They Saw and Heard About in London

British Instruments Show

emphasizes what instruments and controls can do for industry

Abandoning typical austerity, the British Instruments, Electronics & Automation Exhibition filled the Grand Hall in London last May with enough control engineering hardware to challenge the American ISA and Automation shows together. On display: process instruments, data-processing systems, machine tool control systems, data loggers, and nuclear reactor controls.

The fourth British Instruments, Electronics & Automation Exhibition, averaging nearly 5,000 visitors per day for its first five (of ten) days, surpassed all previous years ('51, '53, '55) by bringing together for the first time under one roof all associated techniques of instrumentation, control systems, data processing, and communications. The roof belonged to Grand Hall, Olympia, London, where the 200-booth exhibition held forth from May 7 to 16. It was sponsored by five leading trade associations (all manufacturers):

The British Electrical & Allied Association

The British Industrial Measuring & Control Apparatus Association

The British Lampblown Scientific Glassware Association

The Drawing Office Material Mfrs. & Dealers Association

The Scientific Instrument Association of Great Britain

These associations, working through their joint Exhibition Committee, headed by L. S. Yoxall, managing director of Foxboro-Yoxall, Ltd., maintained direct control of the show.

Contributing this year to the high attendance figures were some 2,690 overseas buyers from 69 different countries, a special delegation of 26 Russian technicians, and the general public. This was eloquent testimony to the great interest in the control engineering work being done today by Britain's engineers and scientists.

Comments from several American visitors underscored the success of the show. For example, SAMA's president R. E. Welch felt that there was no comparable exhibition in the U. S. where such a variety of techniques was presented in a way that showed industrialists what instrumentation and controls could do for them.

The range of equipment at the exhibition was vast. It embraced machine tool control, process control, data logging, analysis instrumentation, data handling systems, and nuclear equipment—about which there's more on the pages following. The many complete control systems reflected joint efforts by the British exhibitors. Most of these are used in Britain's fast-moving nuclear power program.

One section of the show was turned over to demonstrations of Electronics at Work and Play. Here foot-sore visitors could take a break from purely practical matters by observing the tantalizing effect of the Electronic Beer Barrel. Radio-controlled, the barrel moved backwards and forwards and poured out (for the operator only) a selection of light and dark beers.

On the headier side were the conference papers, presented concurrently with the exhibition. The conference themes followed those of the exhibition—automation, nucleonics, education, medical application of instrumentation, industrial applications, computers, and communication and navigation. Top-flight personalities, such as Lord Halsbury, Sir Claude Gibb, Dr. P. Dunsheath, Sir Walter Puckey, and A. J. Young, spoke.

Here's What They Saw and Heard About in London . . .

. . . Machine Tools

Len Coates of Mullard Research Labs (second from left) briefs CONTROL ENGINEERING's European Editor Derek Barlow (far left) on Mullard's Autopilot, an automatic coordinate positioning machine consisting of a work-table, tool carriage and gantry, and associated control circuitry. The tool head moves in increments of 0.001 in. to any desired position over the 24-in.-width traverse and 30-in. longitudinal travel on the work-table. These positions are established by setting the x and y coordinate dials. Positioning control derives from rotation of a toothed scanning disc geared to the lead-screw, which supplies a pulse to the counter circuits for each 0.001-in. incremental movement. On pressing the Auto button, the carriage takes up its preset x and y dial commands. The tool head takes drills up to ¼-in. diam.

Also in the machine tool category was Ekco Electronics' Type E 117, a control system that provides automatic coordinate setting simply by adding a traverse unit to each coordinate lead-screw. The associated control equipment contains no vacuum tubes, but rather a series of Wheatstone bridges adjusted for the desired measurement. A drive unit turns the slave potentiometers in the servo head until voltages in the bridges are balanced out. The system uses two different size motors and a "bang-bang" servo, and has a reset accuracy of 0.0002 in. It sells for about $1,500.

. . . Nuclear Reactor Controls

Elliot Brothers, Ltd., aided by this charming young lady, displayed its ND181 Reactor Simulator—a general-purpose instructional model that can be extended to include a Xenon poisoning computer or a control-system simulator. The ND181 contains (1) a neutron kinetics computer for determining neutron density proportional to reactor power level—computer input signals are analogs of existing power level, source strength, and pile reactivity, while output signals correspond to output power and its logarithm, and pile period; (2) a pile parameters unit for representing kinetic equations; (3) a reactivity computer for providing an excess reactivity signal, and (4) additional controls for varying or switching reactivity steps—these changes represent the effects of fuel depletion, changes in coolant flow rate, and insertion of experimental absorbers.

Sunvic Controls, Ltd., showed control desks for the research reactor controls ordered by West Germany and the Atomic Weapons Research Establishment, and released details on the control system proposed for the 275-megawatt nuclear power station at Berkeley, Gloucestershire. Of particular interest was the monitoring system for detecting burst nuclear slugs. Each reactor will have associated with it two computers to give a daily printout of channel activity from the burst slug system.

. . . Computers

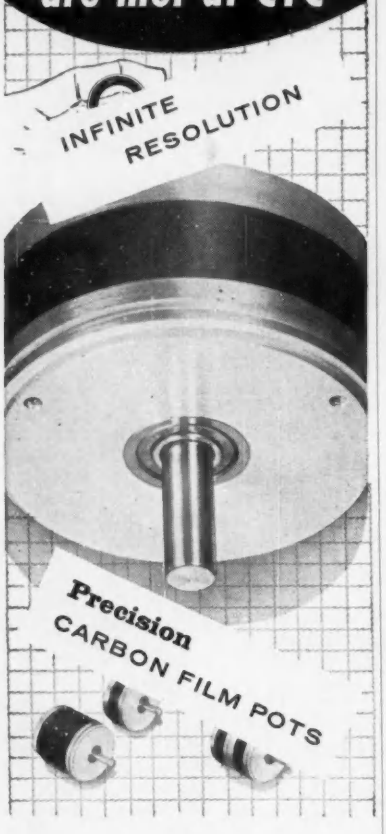
Two of the latest British digital computers made their debut. Shown here is the Metropolitan-Vickers 950, a $55,000 medium-speed computer containing 400 transistors. It's one of the first transistorized models to be put out on a production basis.

An electronic desk calculator by Southern Instruments, selling for about $30,000, enables direct decimal calculations to be made on vector and scalar numbers. Instructions are fed in by tape for a repetitive problem, by plug-board for problems of less than 100 steps, and by keyboard for single calculations. To multiply two complex quantities of 12 digits in the real and imaginary parts takes 9 sec.

In the analog computer field was the standard linear amplifier developed by Ireland's Short Bros. & Harland. Its continuous drift correction results in a residual drift of less than 50 microvolts over an 8-hr period. A low-frequency decade oscillator for servo testing, made up from standard linear computing units, has three linear operational amplifiers arranged to solve a single second-order differential equation, with a discontinuous function unit to give amplitude control. It covers the range of 0.01 to 110 cps with a frequency accuracy of 1 percent. Two outputs in quadrature are available. Oscillation is started by turning a "clamp" switch to unclamp the amplifiers. On reclamping, decay is truly exponential.

(*For more on the show, turn the page.*)

CRITICAL POT SPECS* are met at CIC



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WHAT'S NEW

BRITISH SHOW . . .

STORY STARTS ON PAGE 22

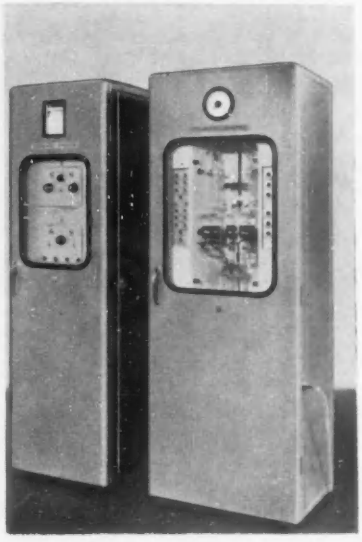
. . . Process Instruments

The most dramatic exhibit in analysis instrumentation was the Titromatic Analyzer at the right, the joint development of Imperial Chemical Industries and Electronic Instruments, Ltd. The analyzer, designed for in-plant use, consists of a chemical unit containing an array of glass vessels controlled by automatic taps, and a control unit for sequencing the titration. It can be connected to the main plant stream, where once every 3 min to once every half-hour the titration procedure is carried out.

. . . Data Logging

U. S. influence was apparent in the data-logging displays. Two data loggers shown by the Associated Automation Co., Ltd., a manufacturing group which includes Panellit, Ltd., closely followed U. S. practice. These were a 50-point system for the Imperial Chemical Co. nylon plant at Wilton and a 100-point system for the French Centrale Thermique de Porchville.

A British approach to data logging



was shown by Sunvic Controls, which is manufacturing a 400-point installation for a polyethylene plant, and is considering a mobile 50-point unit for a chemical company. The latter would be mounted with a Ferranti Mercury computer for on-site plant investigations.

International Federation of Control Shapes Up

The provisional committee assigned at Heidelberg, Germany, (CtE, Dec. '56, p. 33) to plan the formation of an international federation on control science met April 25-26 in Dusseldorf to complete plans for the organizational meeting of the federation. Provisional Chairman V. Broida (France), Secretary G. Ruppel (West Germany) and Otto Grebe (West Germany, Rufus Oldenburger (U. S.), P. J. Nowacki (Poland), and A. M. Letov (U. S. S. R.), were on hand. W. Bamford substituted for the British member, D. B. Welbourne. Last-minute telephone calls from Dusseldorf to Bonn and Moscow cleared the late-arriving Russian member and his "entourage" through Bonn dalliance with their visas. Aside from these minor incidents, all came off as expected. Result: an organizational meeting set for Paris, Sept. 10-12.

Each participating country will send one to three delegates to the Paris meeting. U. S. delegates named by North American Control Council Chairman Rufus Oldenburger to represent this country's technical societies are Harold Chestnut (AIEE), John Lozier (IRE) Rufus Oldenburger (ASME), and J. O. Hougen (AIChE)—alternate. The delegation is expected to nominate Chestnut as the first two-year president of the federation. The Russians will probably support this move, and campaign for A. M. Letov as the second president. If their campaign succeeds, they will then invite the federation to hold its first congress in Moscow in 1960—when Letov is president.

After electing officers at the Paris meeting the federation will consider a proposed constitution drawn up at Dusseldorf by the provisional committee. This proposal calls for a federation which will promote the science of automatic control, covering the theory and application of open and closed loops of physical systems (including servomechanisms). It would carry this out by sponsoring international congresses and by promoting the interchange and circulation of information on automatic control activities in cooperation with existing national and international organizations. Though the federation would have four official languages, English, French, German, and Russian, its official decisions would be recorded in English only.

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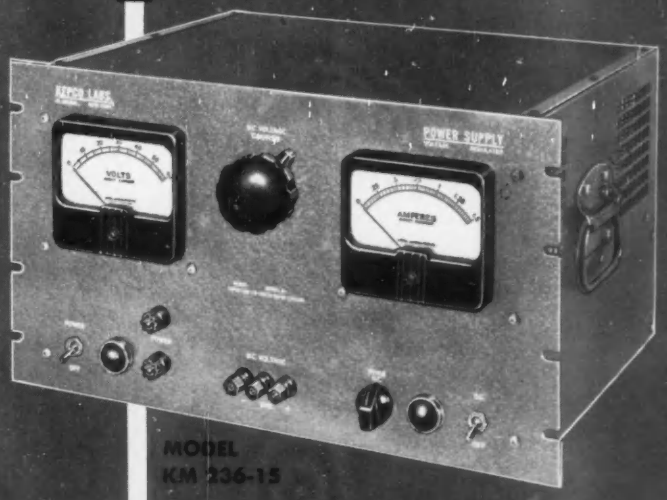

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15 AMPS.

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- **Output voltage within 0.5% during recovery time for line transients 105-125 volts.**
- **Short circuit will not damage supply.**
- **Full current may be drawn at any voltage from 2-36 volts.**

OUTPUT VOLTAGE DC: 2-36 volts continuously variable.

OUTPUT CURRENT DC: 0-15 amperes continuous duty.

REGULATION: In the range 2-36 volts the output voltage variation is less than 0.5% for line fluctuation from 105-125 volts, and less than 0.5% or 25 millivolts, whichever is greater, for load variations from minimum to maximum current.

RIPPLE VOLTAGE: Less than 0.5% or 25 millivolts RMS, whichever is greater.

FUSE PROTECTION: Input fuses on front panel.

OVERLOAD PROTECTION: An automatic current limiting device allows direct shorting of the output terminals without damage to the supply.

POWER REQUIREMENTS: 105-125 volts, 57-63 cycles.

OUTPUT TERMINATIONS: DC terminals are clearly marked on the front panel. Either positive or negative terminal of the supply may be grounded. DC terminals are isolated from the chassis. A binding post is available for connecting to the chassis. All terminals are also brought out at the rear of the chassis. Two terminals are mounted at the rear of the chassis to provide for picking up the error signal directly at the load. This connection compensates for the voltage drop in the wires connecting the power supply to the load.

METERS: Ammeter: 0-15 amperes, 4" rectangular.
Voltmeter: 0-15 volts, 4" rectangular.

CONTROLS: Power on-off switch, DC on-off switch, remote error signal on-off switch, coarse and fine voltage controls.

PHYSICAL SPECIFICATIONS: Rack panel construction. Panel height 12¼", width 19", depth 17". Color Kepco standard gray hammertone. This unit is designed for relay rack mounting or bench use. Carry handles are provided.

OPERATIONAL CHARACTERISTICS: This regulated unit consists of a ferro-resonant line regulator followed by a magnetic amplifier regulator. The ferro-resonant line regulator furnishes well regulated transient free AC power. The high gain magnetic amplifier is used to regulate the DC output voltage to compensate for voltage changes in the power unit for varying load currents. The response time for pulse loads is less than 0.2 seconds.

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Panels, Forums, and Workshops Spark Flight-Test Symposium

Though plagued by an epidemic of speaker substitutions and a backstage squabble with the sponsoring ISA, this year's National Flight Test Instrumentation Symposium (April 30-May 2 at Los Angeles) maintained its position as a drawing card for control engineers. Attendance at this third meeting of the symposium was as good, if not better, than anticipated, and at every event there were glimpses of careful planning by the Symposium Committee. One of the best things done by this group was to pick the Statler Hotel, whose comfortable, blackboard-equipped rooms turned out to be perfect for the unique afternoon workshops.

The dispute with the ISA began shortly before the symposium program was full developed. Symposium organizers won, but only, it was said, because they threatened to turn their back on ISA jurisdiction and hold their meeting on their own if the parent body did not relent in demands for a trade-show accompaniment. Some said that the ISA had stepped in while the program was being formulated with the announcement that a trade show was a requisite for a national ISA conference, and that any ISA group refusing to accommodate a show would be compelled to hold regional meetings only.

• **Pitchmen find the door**—As it turned out, some sort of trade show was held by several companies in Statler suites, and though these were closed during symposium sessions, the feeling was that too many manufacturers' reps got in on the technical sessions with thinly disguised pitches. One panel discussion, on advanced instrumentation techniques, for instance, had a definite vendor orientation and was the weakest area of the program. One out-and-out sales pitch brought counter-claims from other vendors and the meeting nearly became a market place. There was a lot of unfavorable comment about this later on.

The symposium examined a different phase of flight-test instrumentation each day. On the first it tackled "Optimum Aspects of an Instrumentation System", on the second "Limitations of Current Instrumentation Systems", and on the third "Advanced Instrumentation Techniques". Each day, in turn, was divided into morning panel sessions and afternoon workshops, and fortunately for the symposium as a whole, it was mainly the morning panels that were beleaguered by the substitutions, for the discussion leaders who were scheduled (and who showed up) for the workshops were top-notch.

One of the best was T. G. Mac Anespie of The Martin Co., who really stirred up the participants and drew out the comments at a third-day workshop on "Laboratory and Pre-Flight Calibration Techniques". He

T. G. Mac Anspie of The Martin Co. conducts lively afternoon workshop on "Laboratory and Preflight Calibration Techniques"

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APPLICATIONS: Electronic, medical, geophysical, chemical, metallurgical research and development . . . transistor production and circuit design . . . thermocouple calibration . . . null detector . . . recorder driver amplifier . . . and as a general purpose laboratory instrument wherever dc voltage and currents are measured or amplified.

SPECIFICATIONS

Voltage Range (full scale) . . . . . 100μv to 1000v	Accuracy on All Ranges . . . . . ±3% of full scale
Current Range (full scale) . . . . . 100$\mu\mu$a to 100 ma	Maximum Gain as Amplifier . . . . . 80 db ±1.5%
Input Impedance . . . . . 10 megohms below 10 mv, 30 megohms at 30mv, 100 megohms above 30mv	Output Rating . . . . . 1v across 1000Ω
	Output Impedance . . . . . less than 5Ω
	Drift (after 15 min. warmup) . . . . 10μv equivalent input
Impedance Accuracy . . . . . ±1.5%	Price $550.00

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IN THIS ISSUE

✳ The D-695-A Decade Oscillator and some applications

✳ Noise measurements in the Aircraft Industry

✳ An improved optical scanning head for facsimile transmitters

✳ Latest news on synchros

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WHAT'S NEW

and others like him proved the workability of the workshop idea: no prepared speeches; just set the subject and then make sure the discussion centers around it.

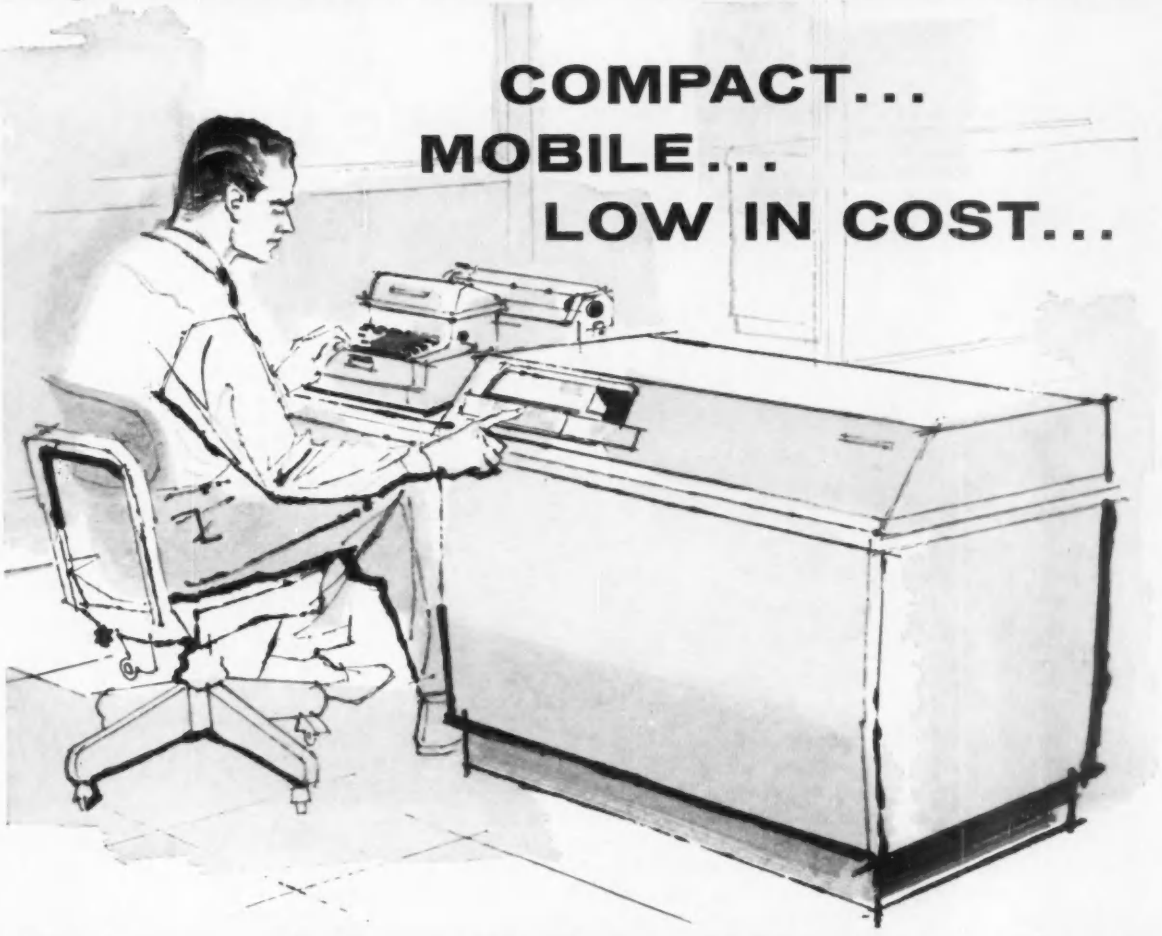
• **Dember leads a good one**—Of the morning sessions, the one on "Limitations of Current Instrumentation Systems" was the best organized and the most productive. Chairman here was A. Dember of the U.S. Naval Ordnance Test Station at China Lake, Calif. Conclusion of the panelists was that there must be concurrent design of aircraft and missiles, and of the instrumentation that goes in them, and that this must be built into the design program at an early stage to avoid costly and time-consuming modifications. Some of the panelists stressed a need for considerable refinement in flight-testing techniques so as not to retard instrumentation development.

A missile forum panel was held each day at the same time as the workshops. These forums considered significant areas in missile instrumentation and were conducted, for the most part, like the workshops: there were short presentations and then the audience took over. One of the best received and most carefully organized was the forum on "Power Spectral Density Techniques". Though the technique is new and difficult to grasp, Chairman C. T. Morrow of The Ramo-Wooldridge Corp. saw to it that it was described in an interesting way. One of his gimmicks: a set of tentative definitions distributed to the audience before the session got under way.

Other sessions that drew praise: "Advanced Recording Techniques", a workshop chairmanned by H. L. Mason, National Bureau of Standards; "Transducers vs. Flight Environment", a workshop led by J. K. Stotz Jr., Grumman Aircraft Engineering Corp.; and "Progress in Magnetic Tape Ground Handling Facilities", a workshop piloted by B. T. Johnson, Boeing Airplane Co., Seattle. Johnson's group discussed two high-speed computers for processing data automatically, the IBM 704 and the 1103A Univac Scientific, and concluded that even these units do not have outputs fast enough to handle the great amounts of data, printed and plotted, that are amassed in flight-tests.

• **Data-recording camera**—In line with data processing, there was an item in one of the hotel suites that

Royal Precision LGP-30 Electronic Computer



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The result of 20 years' experience in the design of electronic computers, LGP-30 puts you in complete control of your own engineering problems. Used right at your desk, LGP-30 allows you to program your own material without planning in detail. You modify equations on the spot, follow your work to completion. Thus, you eliminate much detailed calculation . . . uncover added time for creative engineering.

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- **Operates from regular wall outlet (110 volts AC).**
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- **Unusually large "memory"— 4096 words.**
- **Word length: 32 bits, including sign and spacer bit.**
- **Average access time: 8.5 ms.**
- **Optimum access time: 2 ms.**
- **Lowest cost ever for a "complete" computer.**
- **Nation-wide sales and service.**

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ROYAL TYPEWRITERS • McBEE BUSINESS SYSTEMS

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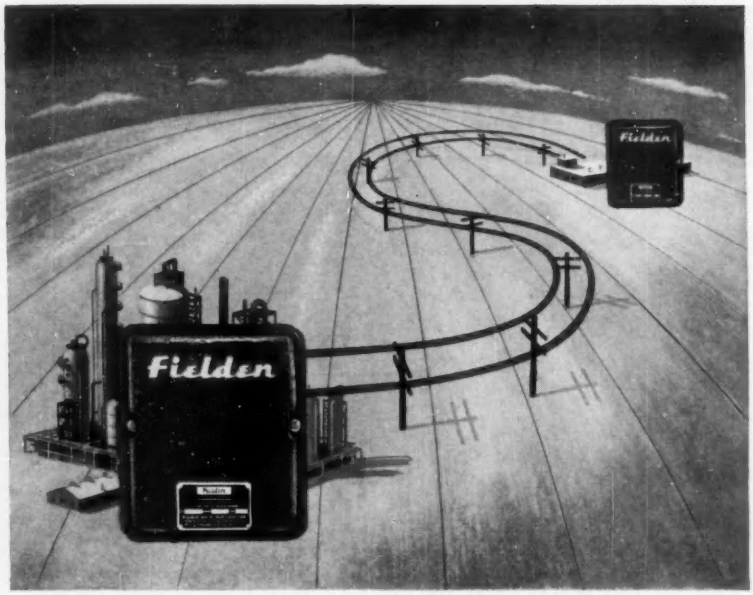

Completely new in concept, the Fielden P-E-P Transmission System not only brings speed and accuracy to remote pneumatic transmission but actually promises to revolutionize pneumatic process instrumentation. Now, with hardly any air lines, you can reproduce air signals up to 5 miles away . . . eliminate transmission lag . . . use pneumatic or mechanical sensing elements . . . and even obtain electrical meter readings between transmitter and receiver.

The Fielden P-E-P System makes this possible by converting any pneumatic signal (from 3 to 15 psi) to 3 to 15 milliamperes D.C. for transmission. It then reconverts the electrical signal to the original pneumatic signal, and feeds it to pneumatic instruments or control devices.

WRAP UP TEMPERATURE AT Fielden

Whatever the temperature problem, Fielden offers a wide range of solutions. Recorders: from money-saving current or voltage types to null-balance recorders of "building block" design. Controllers: everything from "blind" on-off controllers to recording types with full proportional action. Data Centralizers: automatic scanners, manual monitors, multi-point recorders for up to 96 points. Pyrometry Supplies: full line from sensing elements to chart paper.

Send for Literature

Mr. Controls®

Robertshaw-Fulton CONTROLS COMPANY

FIELDEN INSTRUMENT DIVISION
Dept. S, 2920 N. 4th St., Philadelphia 33, Pa.

attracted a great deal of attention from the flight-test people. This was the new Model V Multidata 70-mm data-recording camera for missile tracking developed by Flight Research, Inc., of Richmond, Va. It was said to be able to record missile flights up to 350 miles using a 500-in. focal lens. Nearly all those present from flight-test facilities said their companies are working on, or thinking about, a system of data processing using a computer. Several of these systems are now in operation.

E. O. Spencer of Hughes Aircraft Co., who was general chairman of the symposium, opened it with a word of caution to those engineers

E. O. Spencer, Hughes Aircraft, opens Flight Test Instrumentation Symposium at the Statler in Los Angeles.

who have the tendency to go off on a project half-cocked. These men, he said, should pay more attention to the literature in their fields, because here is where they find the alternate approaches that can mean the solution to their problems.

There were three tours arranged for the conferees. One, to Edwards AFB, featured a visit to the high-speed experimental track facility, where a firing was witnessed, to the new experimental rocket engine test facility, and to the flight-test area. Another tour was to Lockheed's data-reduction facility, and the third was to Consolidated Electrodynamics' new R&D building.

Teleregister Invades Industrial Field

Teleregister Co., best known as builders of electronic reservation systems for airlines, has invaded the industrial field with an electronic inventory system installed at the Hood

CONTROL TRANSFORMER
LINEAR TRANSFORMER
Newest!
MOTOR
TYPE DC-8-C-1
DIFFERENTIAL
TRANSMITTER
MOTOR GENERATOR
Newest!
RECEIVER
RESOLVER
eppc
OFFERS A
COMPLETE LINE
OF SIZE 8
ROTARY COMPONENTS
including
SYNCHROS (all types)
RESOLVERS
D.C. MOTOR
LINEAR TRANSFORMER
MOTOR GENERATOR
Clifton Precision began delivering Size 8 synchros from the production line more than a year and a half ago. Since then production has mounted steadily, and we are now in a position to serve more and more customers with these 7 minute accuracy units.
We have also recently produced a linear transformer and motor generator in the size 8 series.
For information, write or telephone: Sales Dept. 9014 West Chester Pike, Upper Darby, Pa. SUnset 9-7521, or our representatives.
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CLIFTON PRECISION PRODUCTS CO., INC.
CLIFTON HEIGHTS
PENNSYLVANIA

RAMBLINGS ON INSTRUMENTATION

Technological breakthrough ! !
—Highway program moves ahead!

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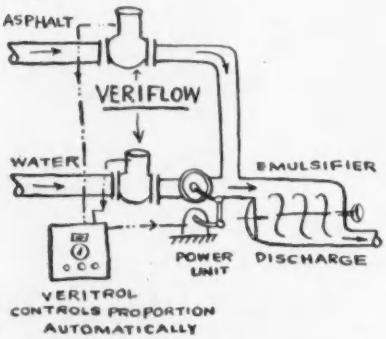

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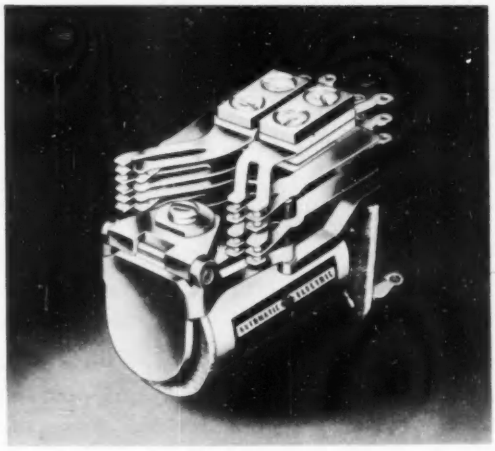
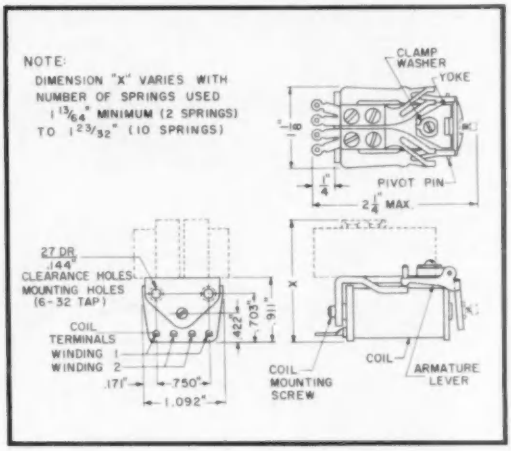
Relay Highlights No.14





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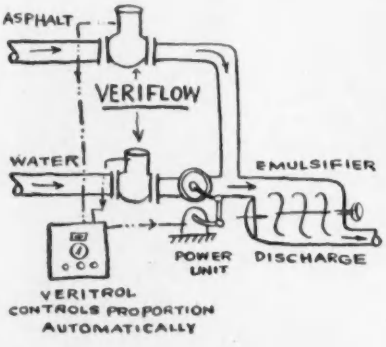

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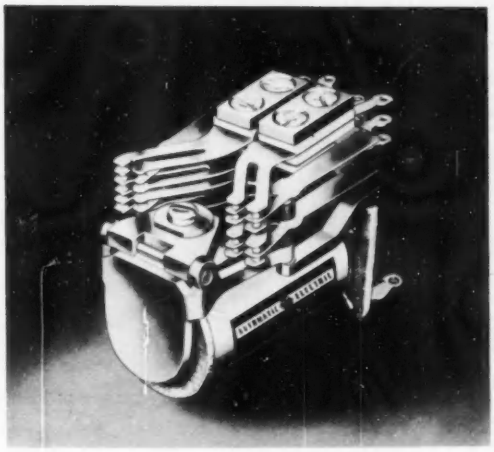

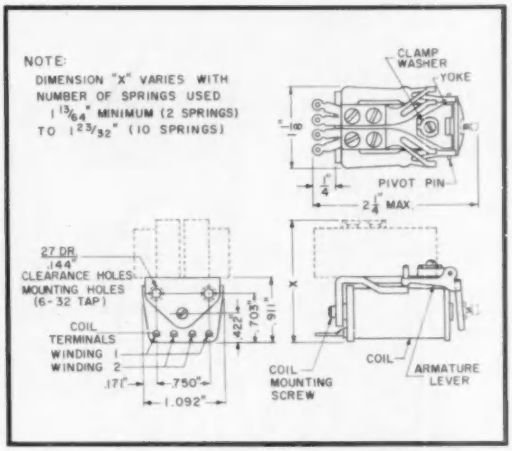

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One of America's great communications systems

SPECIFICATIONS

Operating voltage — up to 150 V DC, 220 V AC.

Contacts — Standard with twin, Code "O" (palladium-silver) . . . make or break 135 watts (maximum 3 amperes, non-inductive load).

Contact spring capacity—maximum of 13 springs per pile-up.

Operating time range — .002 to .050 sec.

Release time range — .005 to .125 sec.

Dimensions — length, 2¼"; height depends upon number of contact springs used — 1-13/64" minimum (2 springs) to 1-23/32" (10 springs); width, 1⅛".

Net weight — 2-1/2 ozs. (approx.).

Coils — single-wound, available with resistances up to 20,000 ohms. Multi-wound coils (up to 3 windings) can be furnished.

Operate and release delays — coils can be provided with armature-end slugs for time delay on operation; heel-end slugs for time delay on release; and core sleeves for time delay on both operate and release.

Class E relays are available as follows:

EQA—Quick Acting

ESO—Slow Operate

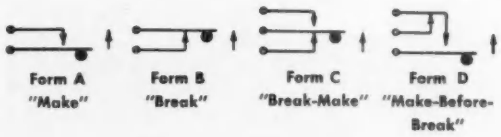
ESR—Slow Release

ESA—Slow Acting (slow operate and slow release)

EFA—Alternating Current

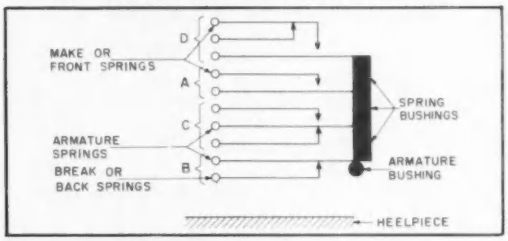
EMS—Snap Action Contacts

STANDARD CONTACT SPRING FORMS



Class "E" relays can be made up in any desired combination (within capacity limits) of the four basic forms (contact spring combinations) shown above in their unoperated "normal" position. Code letters "A" to "D" may be used to describe any desired spring arrangement. The number of forms for each type is indicated by a figure preceding the "form" letter. Forms are specified in the order in which they are assembled, starting from the relay heelpiece. As an example, the arrangement shown below would be specified "1B1C1A1D".

STANDARD ARRANGEMENT OF CONTACT SPRINGS



This is one of a number of Relay Highlights in which we describe the function and operation of Automatic Electric relays and switches. If you would like to see other Relay Highlights in this series, just let us know.

RELAYS **SWITCHES**

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GENERAL TELEPHONE SYSTEM

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185 Bartley Drive, Toronto 16, Canada

General Export Distributors:
AUTOMATIC ELECTRIC INTERNATIONAL, INCORPORATED
Northlake, Illinois

Transient Supply Voltage Problems Plague Rural Machine Tool Users

Panel tackles problem of machine-tool voltage variations. From left, Henry E. Lokay, Westinghouse Electric Corp.; Charles E. Quick, Detroit Edison Co.; Frank C. Fennell, Westinghouse, moderator; Frank T. Doran, Ford Motor Co.; and Kendall H. Spencer, Blanchard Machine Co.

Machine tool users who listened last April to the representative of a power company (Detroit Edison) and a large user (Ford Motor) exchange ideas on who's to blame and what's to be done about troublesome voltage transients in rural distribution lines, didn't get much help in solving their problem, but at least found out that they've got lots of company. That's the impression Managing Editor By Ledgerwood got, at any rate, when he sat in on a special panel session devoted to this problem. It was part of the 21st Annual Machine Tool Electrification Forum sponsored in Buffalo, N. Y., by Westinghouse and attended by about 400 top-level machine tool builders and users, and about 150 Westinghouse engineers.

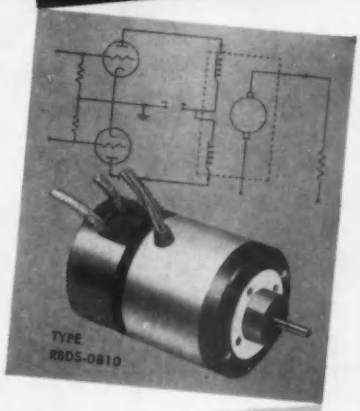
Frank Doran of Ford stated his point bluntly. Large voltage transients in some of his company's rural plants have caused voltage dips as low as 20 percent of rated for two or three cycles, and as low as 50 to 70 percent for many cycles. The control equipment is designed to operate satisfactorily on a plus or minus 10 percent of rated-voltage variation. The obvious result is that relays and starters drop out all over the plant, and the plant shuts down. One Ford plant had several shutdowns in a week, and each one required two to four hours to get going again, a costly business. Mg sets were tried (to add mechanical inertia) and constant voltage transformers (to add electrical inertia). The constant voltage transformers seemed the best interim stopgap, but certainly no final solution to the problem.

• **Quick bears the brunt**—Since the power company supplies the voltage (and voltage transients) everybody hopped on Charles Quick of Detroit Edison as the source of all evil. But

Westinghouse's teleological, or goal-seeking control system operates on the principal of intelligent experimenting. In the unit at the left contour-map lines (hard to reproduce in this photo) lead to the point of highest elevation, the "goal" of the machine.

HOLTZER -CABOT

D. C. Miniature Servo-Motor



Holtzer-Cabot's Type 0810 is well known for its precision performance in gun fire control, radar navigation and radio tuning. It features immediate response to minimum input signal. The armature is designed for continuous excitation from a 24 to 29 volt D.C. source through a 28 ohm series resistor. The field has two 10,000 ohm sections: one for CW and the other for C.C.W. rotation. Full rated motor output is obtained by 6 ma. differential field current.

SPECIFICATIONS: Rating 0.3 oz. in., 6500 R.P.M., .002 H.P.; Diameter: 1⅝"; Field Current 6.0. Milliamps: Armature Current 0.4 amp., Duty Cycle: 4 reversals per minute; Altitude: 50,000 feet; Amb. Temperature: −65° C to +72° C. Designed to meet MIL specs. Send coupon below for additional information.

HOLTZER-CABOT NP

HOLTZER-CABOT MOTOR DIVISION
NATIONAL PNEUMATIC CO., INC.
125 Amory Street, Boston 19, Mass.

GENTLEMEN: ☐ Please send me data sheets on the Holtzer-Cabot Type RBDS-0810 servo motor.

☐ Please have representative call on ..... (date)

Name.....

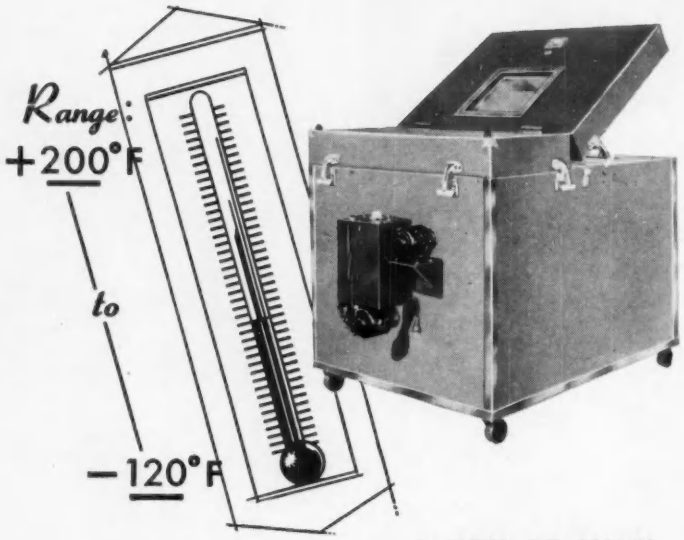
Company.....

Street.....

City..... Zone... State.....

SUB-ZERO AMINCO CABINETS

Produce Extreme Temperatures for Testing and Scientific Evaluation



Aminco's Sub-Zero Cabinets have long been used in science and industry for testing various types of products; accelerated ageing tests of equipment; storage of such items as serums, blood, and chemicals; and shrinking of metal parts for shrink-fitting and assembly. Typical constancies of ±½°F. at −100°F. and ±1°F. at +200°F are maintained. Cooled by means of dry ice.

Special cabinets can be built which will operate up to 600°F.

WORK CHAMBER SIZES	
No. 4-3352	No. 4-3356
24x24x24 in.	18x16x20 in.
$832	**$790**

A FEW OF MANY APPLICATIONS FOR SUB-ZERO CABINETS

- Testing instruments, apparatus, etc. for qualification testing and for determining durability and performance at extreme temperatures.
- Quick ageing of materials.
- Hardening and tempering.
- Biological research.

Complete information, yours on request, in **Bulletin 2209 – Y**

AMERICAN INSTRUMENT CO., INC.

WHAT'S NEW

the power companies have their troubles, too. Quick told the panel that complaints about voltage transients have been coming into his company since 1952. Mostly they're from rural plants with brand new equipment, since these plants are loaded with control devices. What happens is this: the circuit breakers on tie lines cannot drop out fast enough under fault conditions (caused by lightning or similar occurrences) to prevent voltage transients over the whole power distribution system. Faster breakers would help this situation, but this means revamping complete distribution systems, something that is economically unfeasible in the very near future.

The point was brought up that reduced voltage not only causes plant shutdown, but, if the relays don't drop out, also damages the motor and possibly the workpieces and tooling. But Detroit Edison, Quick related, has run tests in which rated voltage was maintained on the controls, but motor voltage was reduced to 10 percent of rated for as long as 30 cycles. Neither the motor, the tools, nor the workpieces suffered any damage. One possibility, Quick said, is that the controls are too sensitive for the motors and machines.

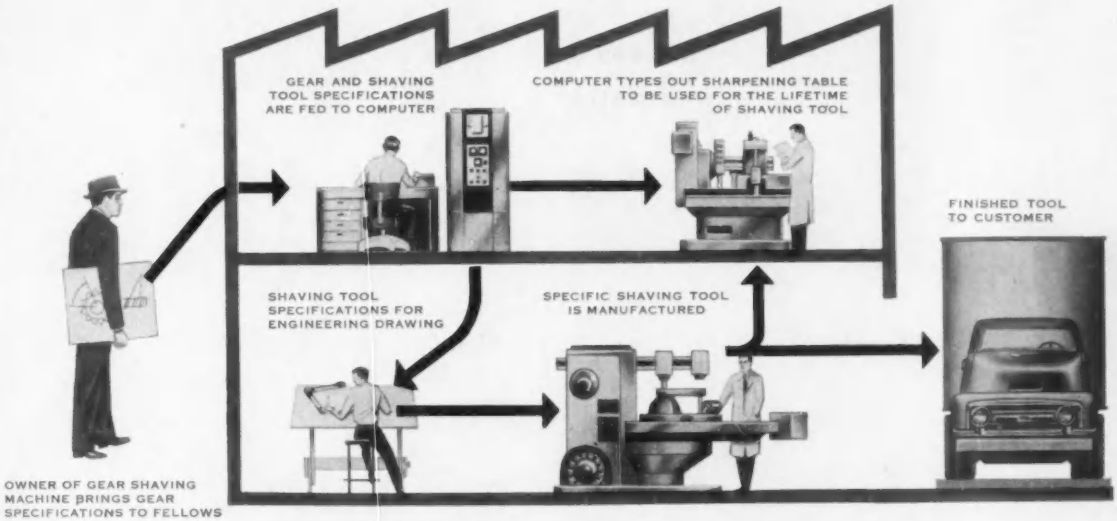
• **A faster/slower relay?**—The problem of controls sensitivity brought forth from the audience suggestions for advancements in relay design. Example: a fast (one-half-to-one-cycle) operating relay that won't drop out if the voltage falls to as low as 10 to 20 percent of rated for two or three cycles. No conclusion was reached on these seemingly diametrically opposed performance specifications for control relays, and it looks like most users will stick with constant voltage transformers while they look for a more satisfactory solution.

There were a few surprises at the forum. One was contained in a paper presented by R. C. Mantanus, vice-president and chief engineer of The Springfield Machine Tool Co., and E. B. Ankenman of Westinghouse's Cincinnati District on a new automatic cycling grinder incorporating Cypac static controls. The surprise came from Ankenman, who said he feels it is easier to design a Cypac system from scratch than construct it from a conventional relay schematic. By said this was the first time he had heard this viewpoint.

Mantanus said Springfield uses single-pole relays in the output stage

(*Continued on page 166*)

Fellows Gear Shaper Co. designs tools 22 times faster with a Bendix Computer


GEAR AND SHAVING TOOL SPECIFICATIONS ARE FED TO COMPUTER
COMPUTER TYPES OUT SHARPENING TABLE TO BE USED FOR THE LIFETIME OF SHAVING TOOL
FINISHED TOOL TO CUSTOMER
SHAVING TOOL SPECIFICATIONS FOR ENGINEERING DRAWING
SPECIFIC SHAVING TOOL IS MANUFACTURED
OWNER OF GEAR SHAVING MACHINE BRINGS GEAR SPECIFICATIONS TO FELLOWS

problem:

For many years, Fellows Gear Shaper Company designed gear shaving tools and cutters for its customers by the same method—extensive layouts combined with manual calculations. A faster and less expensive method was needed.

solution:

In 1955, Fellows turned this problem over to its new Bendix G-15 Digital Computer. Now, gear and shaving tool specifications for each order are typed into the computer. In a matter of minutes all information needed for manufacturing drawings is computed and typed out. The G-15 also generates a sharpening table good for the life of the tool. Pricing tables are prepared automatically and all designs are indexed and recorded on magnetic tape to prevent duplication of engineering work on future orders. Time saving on tool design alone averages 2200%.

Many companies engaged in manufacturing have found ways to lower costs and provide better service by putting the Bendix G-15 to work. A report on how Fellows is cutting costs while cutting gears is available. It contains many valuable ideas. Mail the coupon for your copy.

Bendix Computer

OFFICES IN WASHINGTON, D.C., DALLAS, LOS ANGELES AND CHICAGO

Export Representatives

Computing Devices of Canada, P. O. Box 508, Ottawa 4, Ontario

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BENDIX COMPUTER DIVISION—BENDIX AVIATION CORPORATION
5630 ARBOR VITAE STREET, LOS ANGELES 45, CALIFORNIA

☐ *Please contact me for an appointment to discuss applications of the G-15.* ☐ *Send literature and a copy of the report.*

NAME_____

TITLE_____

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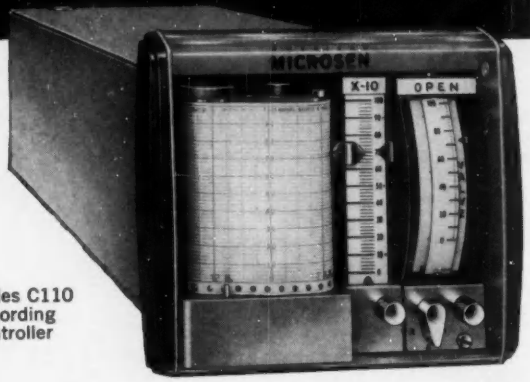
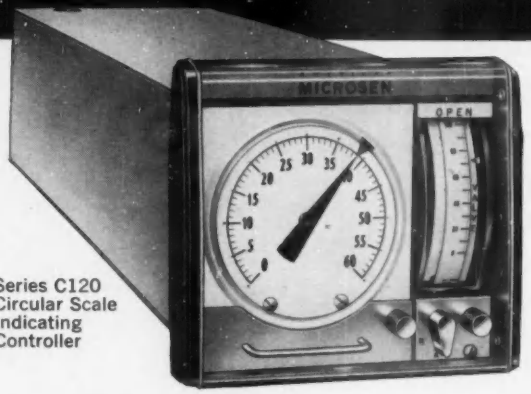
NEW TRANSISTORIZED ELECTRONIC CONTROLLERS Interchangeable for complete versatility



Series C110
Recording
Controller



Series C120
Circular Scale
Indicating
Controller

The new 'American-Microsen' Series C100 Electronic Controllers can be interchanged at the panelboard in seconds. A recording controller to an indicating type . . . a proportional-action controller to proportional-plus-reset . . . slow reset to fast reset – any of these replacements is quickly made by pulling one unit out and plugging in the other.

The controller settings of the 'American-Microsen' System are all calibrated and repeatable. When a controller station is replaced, the proportional, reset and rate settings can be made in advance so the process is on control the instant the changeover is completed. No playing around to tune in the control.

When the process is on manual control during a replacement operation, the controller station stays in balance with the actual valve position. Thus the process can be changed back to automatic control without "bumping" or upset. A unique feature of the 'American-Microsen' System eliminates any "balance" or "seal" position between manual and automatic.

These are but a few of the many functional advantages of the new 'American-Microsen' Electronic Control System. Join the many satisfied users of this new approach to process control. Make certain you have the better control and simplified servicing so essential to higher product quality and greater operating economy. Arrange for a meeting with one of our sales engineers to determine the best equipment for your service. *Write for Bulletin RC100.*

Controller Performs These Functions

Measures input signal from transmitter and records or indicates in terms of the measured variable — pressure, temperature, flow, etc. (The Series C110 records on a 3-inch wide strip chart, the Series C120 indicates on a 4-inch diameter scale.)

Provides means of setting the desired value of the measured variable (set point) and compares actual value with desired value.

Transmits control signal, incorporating proportional, reset, and/or rate actions to operate final control element.

Provides means to operate control element manually with simple switch and manual knob.

Ultra-Modern Features Provided

All functions of recording (or indication), controlling (proportional, reset, and/or rate), and manual valve operation *in a single housing.*

Transistorized controller station for ultimate reliability and long service life.

Printed circuitry and miniaturized components for space-saving simplicity.

Plug-in units for complete interchangeability and ease of maintenance.

Ratio, cascade, and other similar control arrangements, using standard instruments.

Direct bumpless transfer from manual to automatic control with no intermediate position.

DC signals of 1.0 to 5.0 milliamperes for instantaneous distance transmission up to 30 miles.

Controllers are compatible with any unit of other manufacture using the standard 1 to 5 milliampere DC signal.

MANNING, MAXWELL & MOORE, INC.

MAXWELL MANNING & MOORE INC. M&M TRADE MARK

INDUSTRIAL CONTROLS DIVISION • STRATFORD, CONNECTICUT

MAKERS OF 'AMERICAN-MICROSEN' ELECTRONIC INSTRUMENTS FOR MEASUREMENT, TRANSMISSION AND CONTROL

"But I am constant as the northern star"

—Julius Caesar Act III Sc. 1

You know what to expect from CLARE Mercury-Wetted-Contact Relays—always. Their performance is CONSTANT.

Constant contact stability—No contact chatter—none at all.

Constant contact resistance—Repetitive measurements on individual relay contacts are constant to a few milliohms. Resistance of single contacts, including resistance of internal wiring between base terminals, ranges between 25 and 40 milliohms. Contact deterioriation cannot occur in this relay.

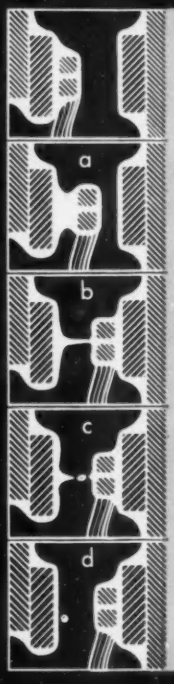
Constant operate time—Varies by only about 0.1 millisecond under constant drive conditions.

Constant pull-in current—Repetitive operating precision of given relay is within 1% of its minimum operating current. This precision is substantially independent of number of operations or ambient temperature.

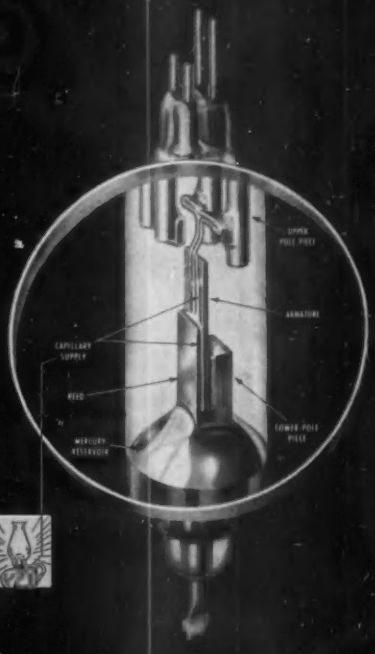
Constant adjustment—Requires no maintenance whatever. No possibility of change in adjustment. This remains true even after thousands of millions of operations.

If you have a job for which none but the best relay is good enough, it can cost you much more to settle for less than this CLARE RELAY. For complete information contact your nearest Clare representative or address C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare & Co., 659 Bayview Avenue, Toronto 17. Cable address: CLARELAY.

Send for CLARE Sales Engineering Bulletins Nos. 120 and 122



Drawings (left) from high-speed photographs show the cycle. (a) Filament of mercury forms between the contacts as they separate. (b) This becomes narrower in cross section and (c) finally parts at two points, allowing globule of mercury to fall out. Mercury flows up the capillary path, replaces amount lost, restores the equilibrium. (d) The momentary bridging of the parting contacts—and the extremely fast break that ends it—minimizes the arc and adds greatly to contact load capacity. Contact closure between the two liquid surfaces bridges mechanical bounce and prevents any chatter from appearing in the electrical circuit.



Contacts of CLARE Mercury-Wetted-Contact Relays are constantly renewed. By capillary action, like that of a lamp wick, a new film of mercury coats each contact with every make and break.

CLARE RELAYS

FIRST in the industrial field

Now! Constant Damping Without Warm-up

Linear Accelerometer
Type LA-500
Shown actual size.

LINEAR ACCELEROMETERS
for Aircraft and Missiles

DESCRIPTIVE DATA

- **RANGE:** Up to ±60 G full scale.
- **DAMPING RATIO:** 0.6 ±0.2 (from −65°F. to +175°F.).
- **LINEARITY:** 1% of full scale.
- **PICKOFF:** Can be provided with 2 potentiometer pickoffs (center taps optional).
- **SIZE:** 1 7/16" dia., 3 1/4" long.
- **WEIGHT:** 1 lb.

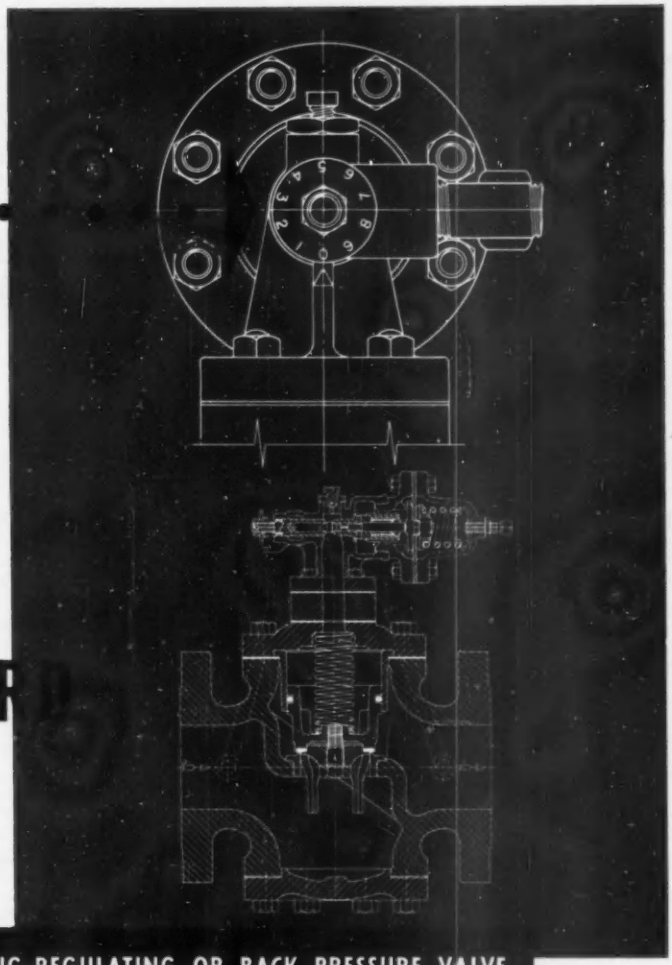
HONEYWELL LINEAR ACCELEROMETERS of the Type LA-500 Series are true linear, non-pendulous type instruments, inherently insensitive to cross-coupling accelerations. These instruments are available in a variation of ranges from ±1 G to ±60 G and can be provided with two potentiometer pickoffs. Essentially constant damping is maintained automatically throughout the entire operating range of −65°F. to +175°F. No warm-up time is required.

The combination of constant damping, high performance, small size and ruggedness makes HONEYWELL LINEAR ACCELEROMETERS of the Type 500 Series ideally suited for aircraft and missile applications where the most severe environmental conditions are encountered. Write for Bulletin LA-500, Minneapolis-Honeywell, Boston Division, Dept. 34, 1400 Soldiers Field Road, Boston 35, Mass.

MINNEAPOLIS **Honeywell** H
BOSTON DIVISION

FOR EXCEPTIONAL CONTROL

a pilot-operated valve with adjustable throttling range



the NEW Improved

CASH STANDARD

TYPE 10 VALVE

- **SELF-CONTAINED**
- **SINGLE SEAT— tight closure**
- **LARGE CAPACITY**

SERVES AS PRESSURE REDUCING-REGULATING OR BACK PRESSURE VALVE

- Improved Y-type strainer in pilot control line protects pilot.
- Simple dial-type range selector permits selection of throttling range required for the most stable and sensitive control.
- Switching control piping easily converts valve from pressure reducing to back pressure operation.
- Diaphragm assembly easily changed to convert to different pressure range.
- Packless design results in low friction and high sensitivity.
- Recommended for: water systems, altitude control, as an unloading valve on extrusion presses, back pressure control, oil refineries.
- For use with water, gas, air, light oils, refrigerants (ammonia, freon).
- Materials: iron, bronze or steel body; bronze or stainless steel trim; monel trim on pilot valve. Composition or metal seat.
- Sizes: 2" to 3" with screwed ends.
  2" to 12" with flanged ends.

WRITE TODAY FOR COMPLETE INFORMATION AND LITERATURE

Dept. F

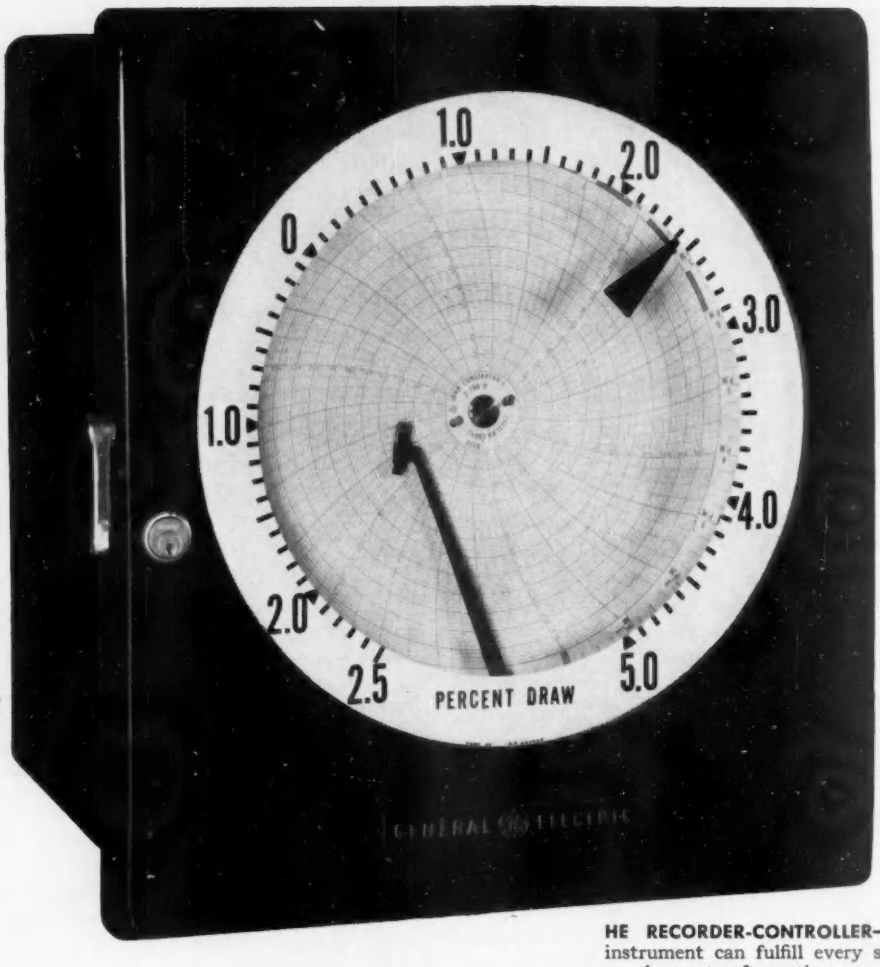
CASH STANDARD

A. W. CASH COMPANY • P.O. BOX 551, DECATUR, ILL.

PRESSURE, HYDRAULIC, TEMPERATURE, PROCESS AND COMBUSTION CONTROLS

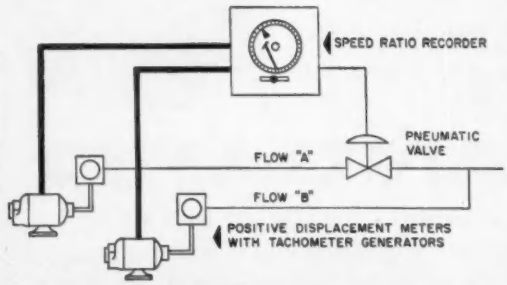
NOW, Control Speed to ±0.1%

GENERAL ELECTRIC'S ROUND-CHART RECORDER GIVES YOU

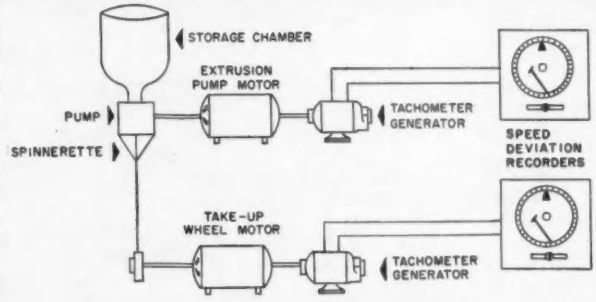


HE RECORDER-CONTROLLER—Versions of this instrument can fulfill every speed measurement requirement of continuous process industries.

HERE'S HOW TO INSTALL GENERAL ELECTRIC'S ROUND-CHART



BLENDING SYSTEM — RATIO



FIBER SPINNING — DEVIATION

with a Low-cost D-c System

FREQUENCY-SYSTEM ACCURACY AT MUCH LESS COST

NOW . . . General Electric offers a d-c speed measurement system that provides the high accuracy usually associated only with a frequency type measuring system—at much less cost!

ACCURACY TO ±0.1%—General Electric's speed measurement system—a combination of one or more Type HE Recorder-Controllers and one or more Type 5BC46 Tachometer Generators—provides accuracy as high as ±0.1% for measurement of speed variables.

MAXIMUM SYSTEM ACCURACY—The extremely high accuracy of General Electric's speed measurement system is possible because of the HE Recorder-tachometer generator combination. General Electric's tachometer generator (Type 5BC46) is a vital component of the precision system. And—for maximum accuracy in continuous process applications—the General Electric tachometer generator should always be used with the HE Recorder-Controller.

SIX SPEED VARIABLES—Continuous process manufacturers can fulfill every speed measurement requirement with the General Electric system. This broad application is possible because the General Electric speed measurement system will measure six speed variables. They are: (1) direct speed (2) speed differential (3) speed ratio (4) speed deviation (5) expanded-scale precision speed, and (6) time in process.

MEASURES OTHER VARIABLES—In addition to providing accurate speed measurement, the General Electric HE Recorder-tachometer generator combination also measures, records, and controls: temperature, pH (acidity), power, volts, amps, viscosity, tension, and gas analysis.

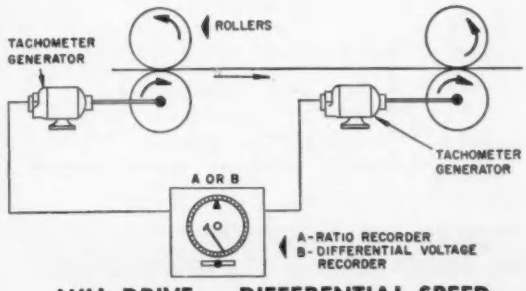
For further information, write to Section 587-9, General Electric Company, Schenectady 5, N. Y., or contact your nearest General Electric Apparatus Sales Office.

GENERAL ELECTRIC'S HE RECORDER OFFERS THESE BENEFITS

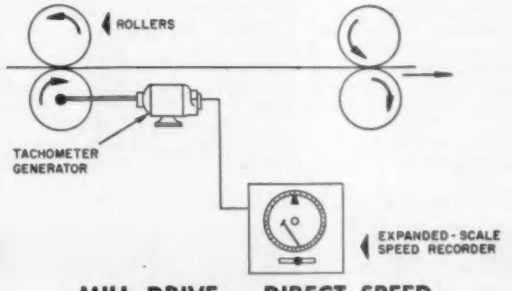
- high production and reduction of scrap because of accurate measurement
- reduced maintenance and reduced operating expense
- sustained accuracy and precision measurement
- continuous, dependable operation—even at 125F ambient
- increased chart readability and simplified chart changing
- continuous standardization, at no additional cost

GENERAL ELECTRIC

RECORDER FOR ACCURATE MEASUREMENT OF SPEED VARIABLES



MILL DRIVE — DIFFERENTIAL SPEED

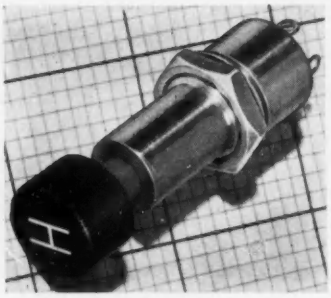


MILL DRIVE — DIRECT SPEED

HETHERINGTON

SWITCHES • INDICATOR LIGHTS • SPECIAL ASSEMBLIES

ENGINEERING NEWS #5

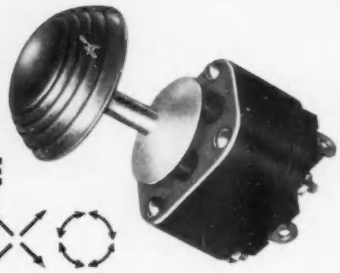


A NON-SNAP SWITCH FOR "KEYBOARDS"

Developed specifically for the keyboards of electronic computers, calculators, and other business machines, the Hetherington B5023 gives the smooth, yet precise action necessary for fast manipulation. Operating pressure is a scant ½ pound — just enough to retain the familiar keyboard "feel."

The versatile 2-circuit, momentary-contact circuitry of the B5023 can also be used as SPST or SPDT. Recent tests have shown a life of better than 1.7 million operations at 5 amps., 30 volts dc. This is far greater than the conservative rating you'll find in Bulletin S-6 if you write for it.

THUMB-OPERATED "TOGGLE" CONTROLS 4 SEPARATE SWITCHES



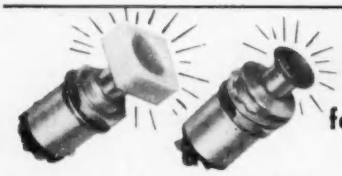
A familiar sight to helicopter pilots is this versatile Hetherington Type F441 Four-Way Switch. Here it is housed, along with other Hetherington Switches, in a handgrip which fastens to the flight control stick. Moving the Switch's thumb-type knob up or down, right or left, operates control motors for hoists or lateral trim.

Housed in the 1-1/64" by 7/8" phenolic case of the F441 are 4 separate momentary-contact switches arranged 90 degrees apart around the base of a thumb-controlled toggle lever. Normally, all switches are "open" and the toggle is centered.

Usually the switch is mounted so that the lever projects through a cloverleaf gate that restricts operation to one switch at a time. Without the gate however, any two adjacent switches may be closed simultaneously. The toggle may also be held outward and moved in an arc to actuate all 4 switches in succession.

Admittedly, the F441 Switch is rather specialized. However, it offers industrial users interesting opportunities to simplify equipment design and operation — by saving space, by "foolproofing" critical circuits, or by making operations easier to understand.

No bulletin is available on this switch as yet, but ratings and a dimension drawing will be sent on request. Ask about the F441.



New SWITCHLITES® for "Human-Engineered" Panels

Wherever switches and indicator lights are used on the same panel, Hetherington *Switchlites* can play a major part in improving panel legibility and operating convenience. For the pushbuttons of these compact snap-action switches contain their own *built-in* indicator lights for easy, direct association of switch and light functions. Moreover, they save greatly on panel space, wiring, installation and removal time.

So many different Hetherington *Switchlites* are now available that only a few of their many features can be mentioned here:

Switch Circuits: SPST, SPDT, DPST, DPDT, or 2-circuit. Up to 15 amps @ 28 v. dc.

Snap-Action: Push, momentary; Pull, momentary; Push-Pull, maintained; Push-Push, maintained; Push-Pull, maintained with auxiliary momentary on "push."

Lamp Circuit: Case ground or separate gnd. terminal. "Hot" lead to separate terminal, thru main sw. contacts, or thru separate built-in sw. circuit. 6, 14, 18, 28 volt AN3140-type lamps.

Pushbutton Lenses: 10 styles, each in 10 transparent or translucent colors. Lettering may be engraved on all.

New Bulletin S-7 gives complete details on all Hetherington *Switchlites*.

Soon! AT LEADING PARTS DISTRIBUTORS

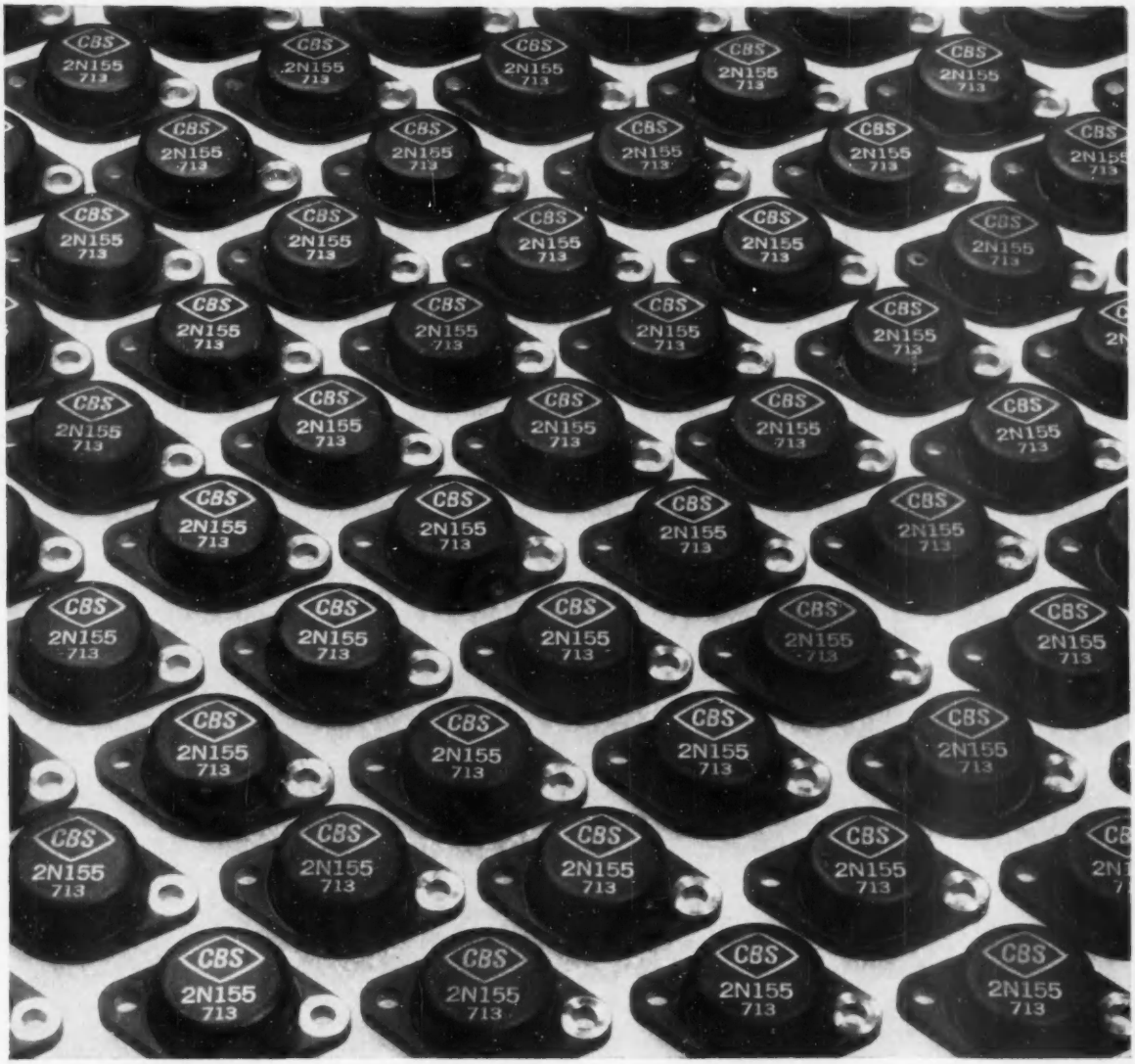
Need Hetherington products for prototypes, breadboard models, special projects, or small production runs? Most popular items will be available at your local electronic parts distributor in the very near future.

For the name of your nearest parts distributor and bulletins of the Hetherington Switches, Indicator lights, and *Switchlites* he carries, write *directly* to: **DISTRIBUTOR'S DIVISION, HETHERINGTON INC., 26 Rittenhouse Place, Ardmore, Pa.**

HETHERINGTON INC. 1420 DELMAR DRIVE, FOLCROFT, PA. • 139 Illinois St., El Segundo, Calif.

better switch engineering for a pushbutton world

1M-144

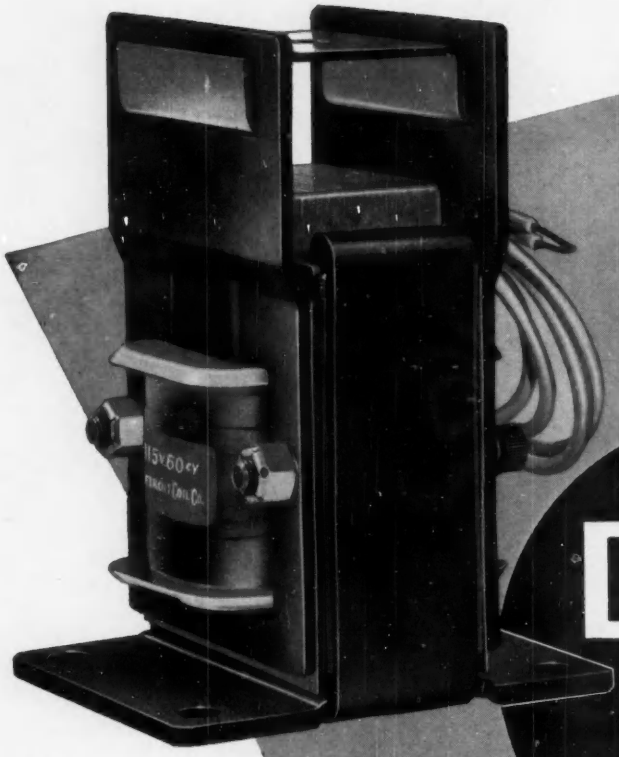


CBS Power Transistors are mass-produced,[1] uniform,[2] stable,[3] dependable[4]...they are your logical choice.[5]

1. They look and are alike because of controlled mass-production techniques.
2. They are uniform electrically because of these techniques.
3. Over 10,000 hours of life have demonstrated their stability.
4. Hundreds of thousands have proved their dependability in actual use.
5. CBS power transistors are *your* logical choice, too . . . for uniformity, for stability, for overall dependability.

CBS semiconductors

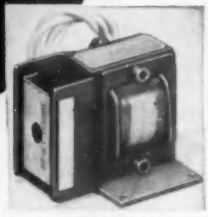
CBS-HYTRON
Semiconductor Operations, Lowell, Massachusetts
A Division of Columbia Broadcasting System, Inc.



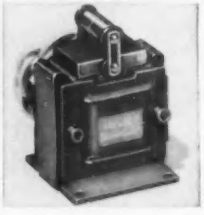
- Up to 30 pounds force. Push or pull.
- Full one inch stroke available.
- Decco shock-mounted for long life.
- High efficiency—silicon steel laminations.
- High moisture resistance.
- Shock absorbing bumpers cushion stroke.

Decco SERIES 50

INDUSTRIAL SOLENOIDS



Your choice of mounts



Push or pull types

Direct current solenoids

Decco's Series 50 offers more power—longer stroke with the same dependable quality and performance that has made Decco the top name in industrial solenoids.

There is a Decco solenoid for every requirement. Built to give better service for a longer time. Solenoids engineered and modified to your requirements. Let us discuss your problems.

For complete information write—

Decco SOLENOIDS THE HEART OF DEPENDABLE AUTOMATION EQUIPMENT

DETROIT COIL COMPANY

2435 HILTON ROAD, FERNDALE 20, MICHIGAN

CMC *model* 226A

UNIVERSAL COUNTER-TIMER

FEATURES:

- ★ Three independent, adjustable trigger-level controls permitting full rated sensitivity at any voltage level between −300 and +300 volts.
- ★ Simplified color-coded controls and direct read-out in kc, mc, sec or millisec with automatic decimal point indication.
- ★ Small voltage increments ordinarily masked by attenuators are easily selected.
- ★ Oscilloscope marker signals facilitate start and stop trigger-level adjustment for time interval measurement of complex wavsforms.

APPLICATIONS:

Multi-purpose instrument designed for precise measurement of Frequency, Frequency Ratio, Period (1/frequency) and Time Interval. Pressure, Velocity, Acceleration, Displacement, Flow, RPS, RPM, etc., may also be measured with suitable transducers. May be used as a secondary frequency standard.

BRIEF SPECIFICATIONS

Frequency Range	0-1,000,000 cycles per second
Period Range	0.000001 cps to 100 kc
Time Interval Range	3 microseconds to 1,000,000 seconds
Time Bases	0.00001, 0.0001, 0.001, 0.01, 0.1, 1 and 10 seconds; external 1 and 10 cycles of unknown (period)
Secondary Frequency Standard	1 mc; 100, 10, 1 kc; 100, 10, 1 cps
External Standard Input	0 to 1 mc

Price $1,100.00

Model 225A—0 cps to 100 kc also available. Price $840.

Complete specifications available from representative in your area or direct from factory . . .

Computer Measurements Corporation Dept. 84-G
5528 Vineland Ave. • No. Hollywood, Calif.

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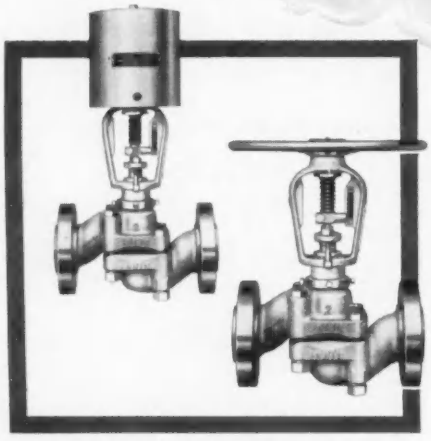
...where Management
...Production and
Maintenance
are concerned!



ANNIN VALVES *meet every test of reliability, response and easy maintenance at low cost*

ANNIN VALVES are the only valves that meet the rigorous requirements of the missile program and the exacting demands of the modern process industries in a single standard construction at no premium.

- **MANAGEMENT** prefers Annin Valves because of low initial cost and low maintenance and spare parts inventory.
- **PRODUCTION** men prefer Annin Valves because of longer on-stream service and better product control.
- **MAINTENANCE** men prefer Annin Valves because of ease of maintenance and simplicity of modification for other services.

ANNIN *Control* **VALVES**

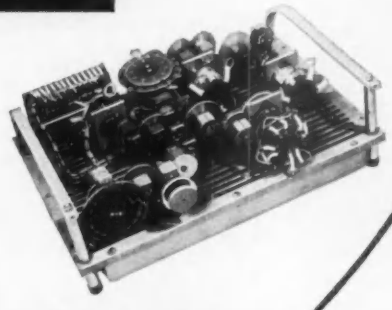
THE ANNIN COMPANY
DIVISION OF THE ANNIN CORPORATION
6570 Telegraph Road, Los Angeles 22, California

now there are two

complete lines of precision servo-mechanical parts by

Reeves
INSTRUMENT CORPORATION

STANDARD



MINIATURE

"packaged precision" for prototype or production assemblies

Complementing and expanding Reeves' well-known line of STANDARD Servo-Mechanical Parts, a comprehensive new series of MINIATURIZED Components is now available. This new line will be of special interest to engineers working on 400-cycle servo applications, and offers the following features:

- Low inertia for 400-cycle systems.
- Includes a very complete selection of components, slotted mounting plates, hangers, dial assemblies, couplings, differentials, and mechanical and electrical stop assemblies, produced to high precision standards.
- A wide range of Class II precision gears—20° pressure angle; 64, 96, 120 diametral pitches.
- Unique "T" nut assembly for ease in hanger mounting provides continuous adjustment parallel and perpendicular to mounting plate slots.
- Parts are designed for ⅛" shafting.

REEVES INSTRUMENT CORPORATION
A subsidiary of Dynamics Corporation of America
209 East 91st Street, New York 28, New York

Reeves' new complete Servo-Mechanical Parts Catalog illustrates and lists the new MINIATURE line, as well as the full line of STANDARD parts for use with ¼" shafting.

REEVES INSTRUMENT CORPORATION
A subsidiary of Dynamics Corp. of America
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Fill in and mail the coupon now to receive your copy of the new catalog.

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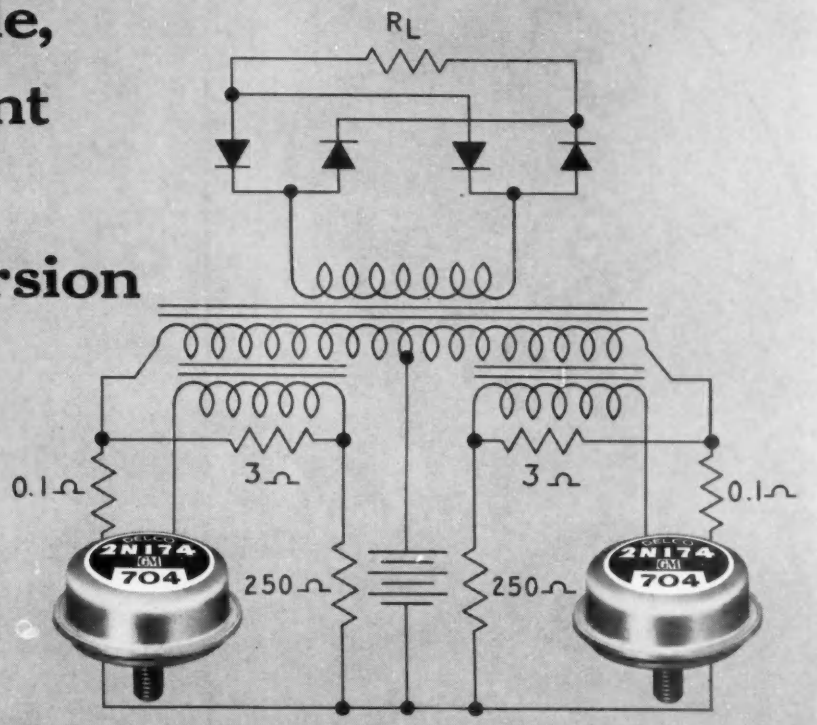
4RVS7

Reliable, Efficient DC Conversion



Industry's Highest Power Transistors

Low saturation voltage of Delco Radio 2N173 and 2N174 opens new opportunities for converter economy, efficiency and reliability

The excellent electrical characteristics of Delco High Power transistors permit the conversion of *low* DC voltage to *higher* DC voltage—with a high degree of efficiency—in a wide range of applications. This proved performance offers greater reliability than will be found in corresponding vibrator circuits.

The low saturation voltage of Delco 2N173 and 2N174 transistors also reduces their internal power dissipation in conversion applications to an insignificant degree so that little self-heating is apparent. The result is an overall economy which permits converters of smaller size . . . important in many applications.

TYPICAL CHARACTERISTICS

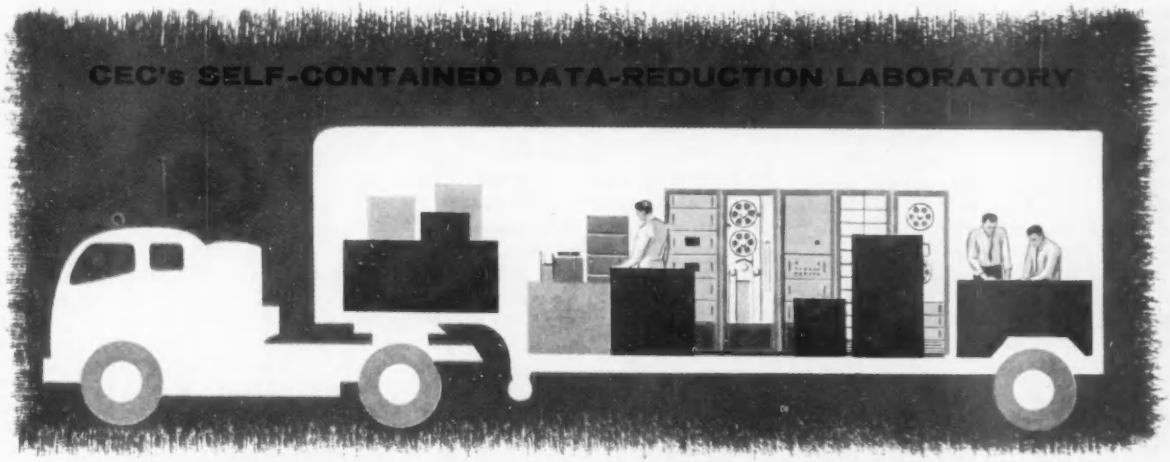
	2N173	2N174
Properties (25°C)	12 Volts	28 Volts
Maximum current	12	12
Maximum collector voltage	60	80
Saturation voltage (12 amp.)	0.7	0.7
Power gain (Class A, 10 watts)	38	38
Alpha cutoff frequency	0.4	0.4
Power dissipation	55	55
Thermal gradient from junction to mounting base	1.2°	1.2°
Distortion (Class A, 10 watts)	5%	5%

DELCO RADIO DIVISION OF GENERAL MOTORS
KOKOMO, INDIANA

Best solution for high-speed flexibility

Put your data-processing lab on wheels

These Trailer Labs—designed and built by Consolidated's System Division—soon will be delivering fast, on-the-spot test data for several aircraft companies. Buyers know that the only efficient location for a data-processing center is at the site where the work is being done. CEC solved this problem with an efficiently designed, integrated system custom-built to do a precision job anywhere. Raw data can be introduced in the form of analog information which is processed at high speed to digital form as punched cards or tabulated summary sheets. Your company can profit with this high-speed flexibility. Let CEC's System Division show you how quickly a custom-designed Trailer Lab pays for itself. Contact your CEC field office for complete information.



Your company can take advantage of this convenient high-speed system...and at no extra cost. For proof, contact your nearby CEC field office, or write for Bulletin CEC 1304-X42.

Systems Division

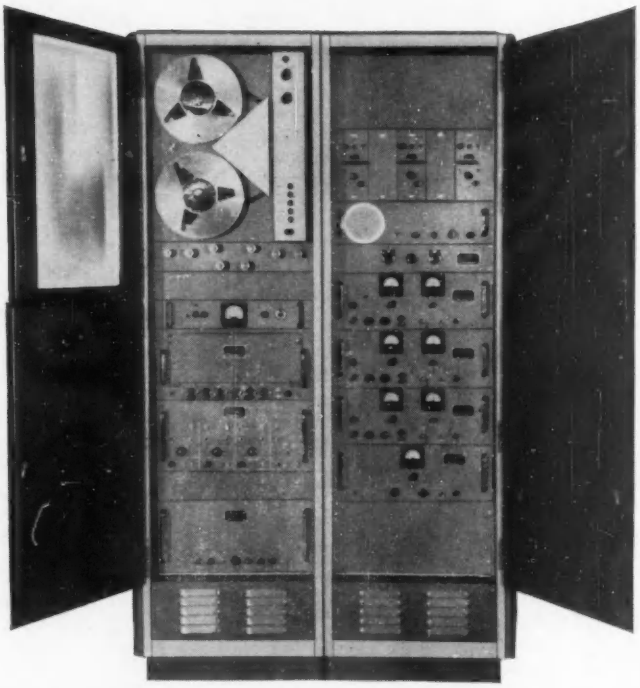
Chemical Analysis · Process Monitoring · Dynamic and Static Testing

Consolidated Electrodynamics

300 North Sierra Madre Villa, Pasadena, California

OFFICES IN PRINCIPAL CITIES THROUGHOUT THE WORLD

NEW UNIVERSAL SYSTEMS



meet 90% of magnetic tape data recording needs

You get all the precision and accuracy of a custom design *and* the off-the-shelf availability and dollar savings of a "package" design in Davies new Universal Tape Systems.

Every component has been designed to provide maximum flexibility consistent with overall system accuracy. Interchangeable electronics match the system to *your individual requirements* . . . now and for years to come. Specify a Universal System that satisfies your *immediate* requirements . . . adding tracks of data capacity as requirements grow.

Any one of the maximum of fifteen tracks provided can carry data recorded by any one of the three major techniques. Interchangeable Direct, FM, and PWM electronics assure you a *vital* data recording system . . . able to handle each new job as it arises. Standard options are also available to meet the special needs of telemetering and multiplexed data.

Among the features of a Davies Universal Tape System never before available in "package" equipment are six tape speeds at the flip of a switch . . . automatic switching discriminators that match tape speed at the transport . . . precise phase coincidence of data among all tracks . . . and facilities for electronic flutter-and-wow compensation. Every item has been proved through years of service in jets, missiles, and on the ground.

Here's a brief rundown of the options available to you when specifying a Davies Universal Tape System that will grow with your recording requirements:

Transport: Standard transport offers up to six speeds, selectable at the flip of a switch. Precision 10½″ or 14″ reels available for 1″ or 1½″ tape. Three-speed transport optional for PWM systems.

Heads: In-line multitrack heads permit up to 15 tracks on 1½″ tape, assure precise time and phase coincidence of data among all tracks. Separate record and playback heads provided. Interleaved head stacks permitting up to 30 tracks on 1½″ tape, optional for telemetering, other applications not requiring data coincidence.

Direct Recording electronics record and playback data from 100 to 100,000 cps. Ideal for high frequency data, also for recording complex wave forms made up of many frequency multiplexed signal channels. Bandpass type discriminators provided for recovering multiplexed data.

FM electronics frequency modulate a stable carrier with the data, to provide extremely accurate data reproduction, independent of tape variations.

Pulse Width Modulation (PWM) electronics permit up to 90 channels of quasi-static data on each tape track. All PWM electronics are compatible with standard keyers and decoding equipment.

Flutter-And-Wow Compensation electronically eliminates the effects of tape speed variation. Included as standard equipment whenever discriminators are used for data recovery, they can be accommodated by every Universal Tape System. Compensation permits FM channels of a Universal Tape System to preserve a high signal-to-noise ratio—better than 50 db at 30 ips, for example.

COMPLETE INFORMATION *on Davies new Universal Tape Systems, and how they can satisfy your magnetic tape data recording needs is provided in Bulletin 2701. Write for your copy to Minneapolis-Honeywell Regulator Co., Davies Laboratories Division, 10721 Hanna Street, Beltsville, Maryland. Or call Webster 5-2700.*

MINNEAPOLIS **Honeywell**

DAVIES LABORATORIES DIV.

Obtain your Scotch Brand recording tape for all instrumentation recording needs at your nearest Honeywell Industrial Sales Office.

NOW-PORTABLE
400 cycle power

This new frequency changer makes it possible to provide well regulated 400 cycle power conveniently and quickly. This unit, Model FCR 250, is extremely useful in a wide variety of applications including testing, production, airborne frequency control, computers, missile guidance system testing, and in practically any application where the use of 400 cycle power is advantageous.

Model FCR 250 is only one of a complete line of frequency changers available from Sorensen . . . the authority on controlled power for research and industry. Write for complete information.

ELECTRICAL CHARACTERISTICS

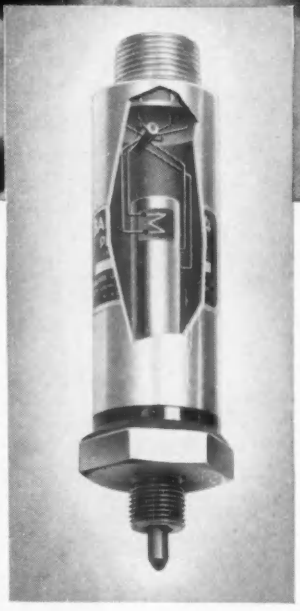
Input	105-125 VAC, 1 phase, 50-65 cycles
Output voltage	115 VAC, adjustable 105-125V
Output Frequency	320-1000 cps in two ranges
Voltage regulation	±1%
Frequency regulation	±1% (±0.01% with auxiliary frequency standard fixed at 400 cycles)
Load range	0-250 VA

MODEL FCR 250

SORENSEN & COMPANY, INC. Sorensen STAMFORD • CONN.

In Europe, contact Sorensen-Ardag, Eichstrasse 29, Zurich, Switzerland, for all products including 50 cycle, 220 volt equipment.

Eardrums can sometimes double as pressure gages . . . BUT



SR-4 Fluid Pressure Cells are made in standard units with capacities as low as 15 psi and as high as 50,000. With pressure converted to proportional electrical voltage, the instruments for reading changes may be located at any remote point.

Use SR-4® Fluid Pressure Cells to measure and control all industrial pressures . . . safe, rugged, accurate to ± ¼%

The skin diver's eardrums are a kind of "go no-go" gage that tells him when he's down as far as he can go. But popping eardrums aren't recommended for performing accurate industrial pressure measurements!

SR-4 Fluid Pressure Cells will measure absolute or differential pressures consistently to less than ± ¼% accuracy! Using well-known SR-4 Bonded Wire Strain Gages, these transducers convert pressure changes directly into a varying electrical signal. This signal can be fed to Baldwin indicators, recorders, controllers or other instruments in a system. There are no moving parts to wear out, no long pressure lines with possible leakage and fire hazards. Remember, a system is only as accurate as its transducer.

If you have pressure measurement problems, a B-L-H representative will be happy to help you—in selecting the proper transducer or in engineering a complete pressure measuring system.

Write today to Dept. A for your free copy of Bulletin 4306, showing the wide range of SR-4 Fluid Pressure Cells.

BALDWIN · LIMA · HAMILTON

Electronics & Instrumentation Division

Waltham, Mass.

SR-4® strain gages • Transducers • Testing machines

COMPACT, CONVENIENT *three-high stacking of the new adjustable Sola Constant Voltage DC Power Supply is shown in the typical laboratory bench setup above. Below, engineer "dials" specific test voltage desired from each of the three standard models of "DC Solavolts" shown.*

A versatile DC supply for men who design or test electrical and electronic equipment prototypes

Do you design or test "prototypes?" If so, and you're seeking a laboratory source of high-current DC voltage, it will pay you to use the "DC Solavolt." It's a moderately-priced, adjustable, regulated dc power supply that provides unusual stability with intermittent, variable, or pulse loads. Output voltage is regulated to within ±1% though supply voltage may vary as much as ±10%. Ripple is held to 0.1% or less.

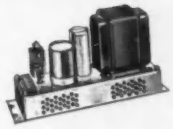
Electrical specifications of the six stock "DC Solavolts" available appear in the table below:

All Inputs 100-130 volts, 60 cps

Catalog Number of Stock Units	Regulated Adjustable Output Voltage Range	Rated Loadings in Amperes		Ripple* Voltage— % of Total Output
		At max. Voltage Setting	At min. Voltage Setting	
28510	5-35	7.0	7.0	0.10
28520	25-60	4.0	6.0	0.05
28530	30-90	2.8	4.0	0.04
28540	60-180	1.4	2.0	0.03
28550	150-250	1.0	1.5	0.02
28560	250-400	0.6	0.75	0.02

**Figures in this column cover ripple voltages measured at full rated load and input of 115 volts.*

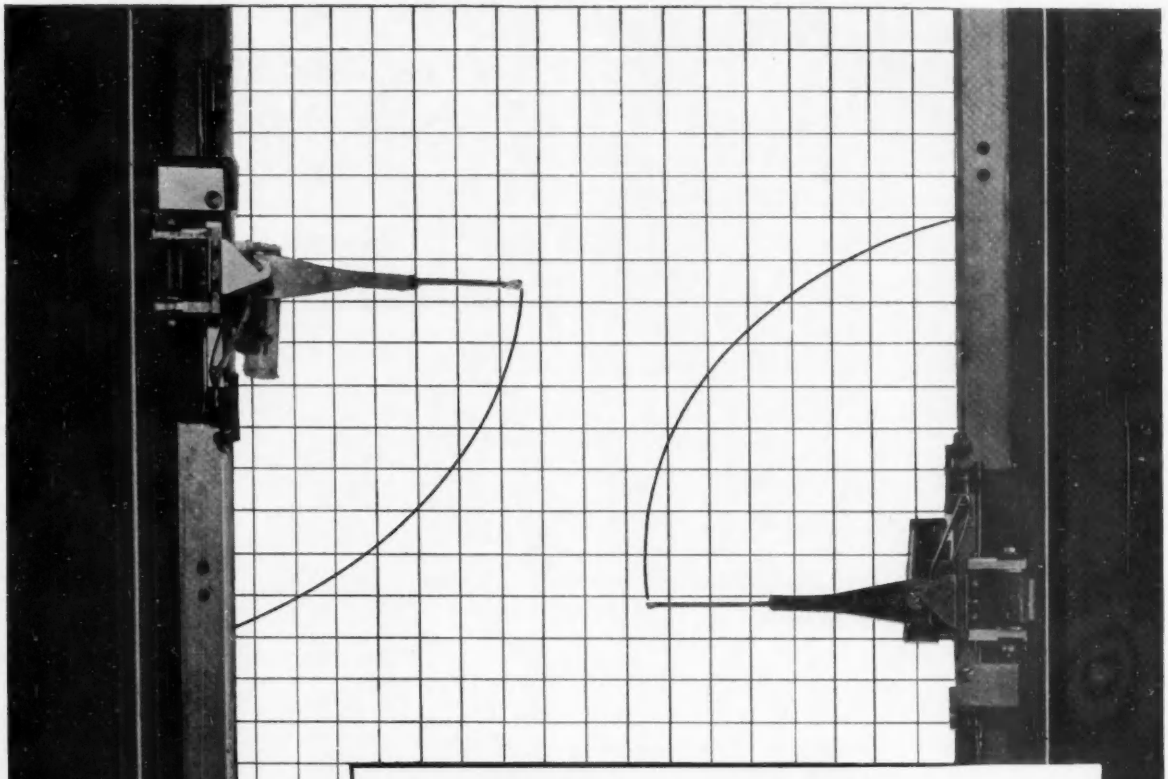
Along with these laboratory standards of performance, the DC Solavolt offers compactness, low weight, high efficiency, and high short-time overload capacity. All stock models occupy only 7" of height and 12¼" of depth on a standard 19" relay rack frame. There are no tubes to replace, no compensating adjustments are needed, and no maintenance is required. Carrying handles, available as accessory equipment, provide "one-man" portability and self-stacking. Your local electronic distributor, who stocks the DC Solavolt, will be happy to give you further information.



Write for Bulletin 26G-DC-245
SOLA ELECTRIC CO.
4633 W. 16th Street, Chicago 50

SOLA *Constant Voltage* **DC POWER SUPPLIES**

CONSTANT VOLTAGE TRANSFORMERS • LIGHTING TRANSFORMERS • CONSTANT VOLTAGE DC POWER SUPPLIES
SOLA ELECTRIC CO., 4633 West 16th Street, Chicago 50, Illinois, Bishop 2-1414 • *NEW YORK 35: 103 E. 125th St., TRafalgar 6-6464 PHILADELPHIA: Commercial Trust Bldg., Rittenhouse 6-4988 • BOSTON: 272 Centre Street, Newton 58, Mass., Bigelow 4-3354 • CLEVELAND 16: 19115 Detroit Rd., EDison 3-2223 • KANSAS CITY 2, MO.: 406 W. 34th St., Jefferson 4382 • LOS ANGELES 23: 3138 E. Olympic Blvd., ANgelus 9-9431 • SOLA ELECTRIC (CANADA) LTD., TORONTO 17, ONTARIO: 102 Laird Drive, Mayfair 4554 • Representatives in Other Principal Cities*



TO KEEP PACE A COMPLETE LINE OF PLOTTING AND RECORDING EQUIPMENT FROM EAI

With recent advances in simulating and computing techniques, the demand is greater than ever for the high speed, precise recording of output data.

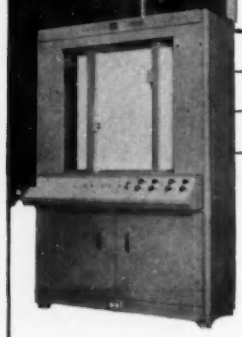
That is the reason why Electronic Associates, Inc., as part of its program of leadership, offers a complete line of plotting and recording equipment from multiple channel strip chart recorders to analog or digital X-Y plotting of 1 or more pairs of variables.

In addition to this high speed, PACE Plotting and Recording Equipment assures you of an accuracy and reliability that has earned it the title of the "royal family of recording equipment"

For a demonstration or for rental of time, contact our Computation Centers. There's a Center serving Eastern Industry in Princeton, N. J.—one serving Western Industry in Los Angeles, Calif.—one serving European Industry in Brussels, Belgium. Please address all inquiries to: Electronic Associates, Inc., Dept. CE7, Long Branch, N. J.

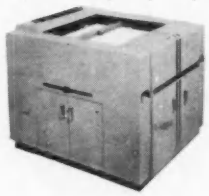
ELECTRONIC ASSOCIATES Incorporated • • • SETS THE PACE (PRECISION ANALOG COMPUTING EQUIPMENT)

LONG BRANCH, NEW JERSEY

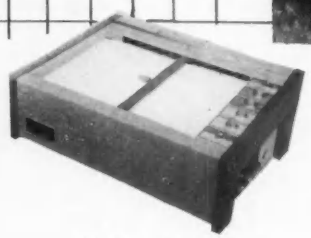


Variplotter Model 205N—for use when record must be viewed from remote location.

Six Channel Recorder, Model 1902A—a strip chart recorder with push-button controls.

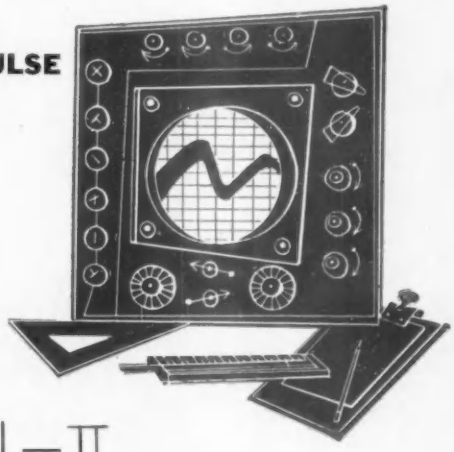


Variplotter Model 205 K & L*—established leaders in large scale, high-accuracy recording.



Variplotter Model 1100D—versatile table-top X-Y Recorder.

*Variplotters: When equipped with a special function generator unit, all Variplotters will produce non-linear functions of one or more variables. Other accessories available. Information on request.



New Centers for Control—II

Oil and airplanes have hypoed control activity in Texas. Last month McGraw-Hill's Dallas News Bureau Chief, Kemp Anderson, sent in this report about the twin cities of Fort Worth and Dallas:

Texas—"You ain't seen nothing yet"

"Texans have watched a steady expansion of activity in controls and instruments during the past ten years. But just recently, the pace has accelerated at a startling rate. And instrument specialists in the area brag that 'you ain't seen nothing yet'.

"Behind the recent surge is the tremendous expansion of aircraft and missile operations in the Fort Worth-Dallas area. Between the two cities, Texas now boasts the second biggest aircraft production section in the U. S. The oil industry has lent a helping hand, too. Most of the major producers have set up major research facilities in the area—that includes Socony Mobil Oil Co., Atlantic Refining Co., Sun Oil Co., and Gulf Oil Corp."

Platform for controls

Development of the B-58 breathed new life into Convair's Fort Worth operations. From a control standpoint, the B-58 represents a radical concept in design philosophy, so much so that some engineers have called the aircraft "a platform for control systems". Its electro-mechanical-hydraulic control systems perform such functions as: 1) automatic control of Mach number, altitude, and heading, 2) three-channel stability augmentation, 3) automatic g-limiting, including constant stick force per g, 4) control-stick steering, 5) artificial stick feel, and 6) automatic adjustment of ailerons. It's hard, in fact, to find any control operation or function that can't be done automatically in the B-58. But Convair engineers are not content: now they're developing equipment to *test* automatically this and other modern weapons systems.

Regulus wears a Dallas brand

Chance-Vought Aircraft, Inc.—developer of the Regulus, the Navy's first surface-to-surface missile—is another aircraft biggie. Sales last year totaled $118,186,055, and employment reached more than 16,000—and there is more expansion planned for

NEW
ELECTRONIC GALVANOMETER

dc null detector

micro-microammeter

microvolt level dc amplifier

microvoltmeter

Sensitive - Rugged - Versatile

Functionally equivalent to suspension galvanometers, but with far greater versatility, the Model 204A is the ultimate for DC null detection in low level bridge and potentiometer circuits. KIN TEL's chopper stabilized, all transistor design provides extreme sensitivity and rugged durability superior to conventional moving coil or electronic galvanometers.

Immune to overload and shock, the current sensitivity of the Model 204A is 20 times greater than the sensitivity of high quality, mechanical current galvanometers. As a voltage galvanometer, the extremely high power sensitivity of the Model 204A makes it superior to low impedance moving coil instruments. This reliable, general purpose unit is ideal for use as a direct reading indicator for strain gage thermocouple and other current or voltage measurements in industry or laboratory. The 204A's simplicity of operation makes it the key to efficient production line testing. Its unequalled stability makes it ideal for low level DC amplification to extend the range of recording and other measurement instruments.

Representatives in all major cities.

A dozen good reasons why KIN TEL's Electro-Galvo solves your low-level dc measurement problems

1 20 Micro Microamps Per Division Sensitivity

2 ± 10 Microvolts to 10 Volts or ± 0.001 Microamp to 1 Milliamp Full Scale Sensitivity

3 Withstands Extreme Overload with No Zero Offset

4 Transistorized — Rugged — Insensitive to Shock, Microphonics, Position

5 Floating Input

6 7 Voltage or Current Ranges

7 10,000 Ohm Input Resistance

8 10^{-14} Watts Full Scale Power Sensitivity

9 Equivalent Built-in Ayrton Shunt — No Accessories to Buy

10 Use as Stable DC Amplifier with 1 Volt at 1 ma Output

11 Less than 2 Microvolts Drift

12 Less than 1 Microvolt P-P Noise

Model 204A Price $325.00

KIN TEL
(KAY LAB)

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CALIFORNIA • BROWNING 7-6700

1957. Temco Aircraft Corp. started in 1945 as a subcontracting firm. Last year, it made its most significant advances by winning three prime research and development contracts. Temco's 1956 sales reached $90.3 million—almost double 1954's $59.2 million. Bell Helicopter of Fort Worth reported $56 million in helicopter sales last year, an increase of 15 percent over 1955.

TI—a Texas saga

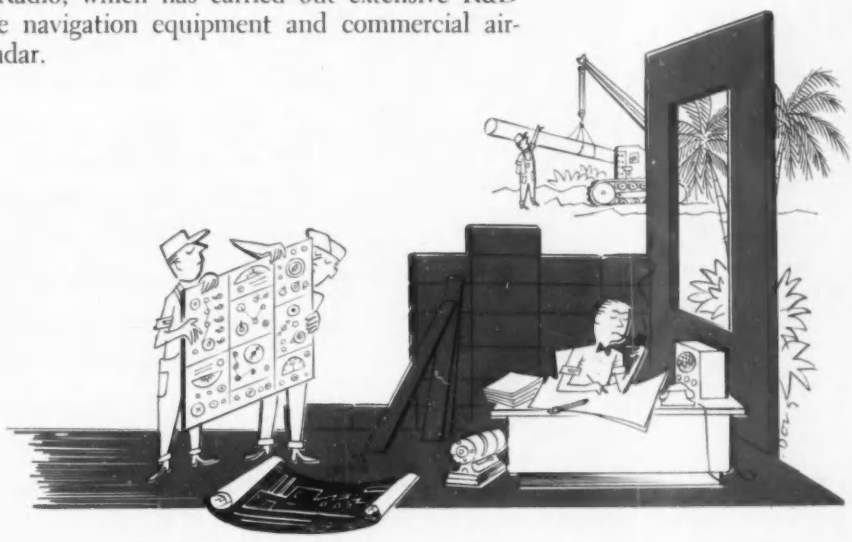
But probably the most fabulous Texas success story is the one they tell at Texas Instruments. Ten years ago TI was a tiny company specializing in geological instruments and surveys; sales were under $2.5 million annually. Last year, TI grossed $45.7 million—a 70-percent increase over 1955, and President J. E. Jonsson predicts that sales may reach $65 million in 1957.

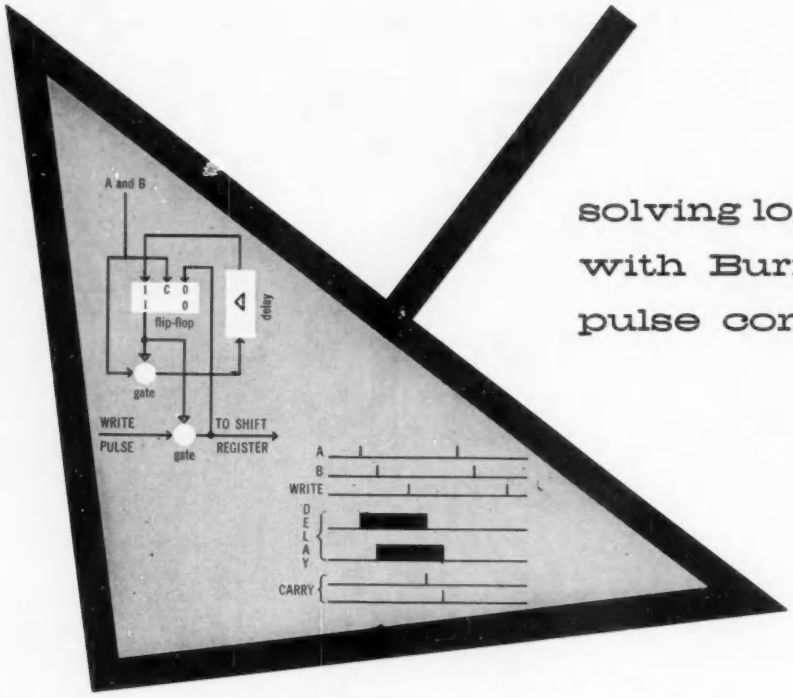
Today, TI is a multi-headed corporation. Its Apparatus Div. produces complete electronic and electromechanical systems for missile guidance, submarine detection, infrared detection, radar, and radar control apparatus. Sales: $12.8 million per year with a $25 million backlog. TI's Industrial Instrumentation Div. still produces geophysical instruments, primarily for the oil industry. Its Transistor Div. is the biggest supplier of silicon transistors in the world. In addition, TI makes other semiconductor components and has invaded the telemetering equipment business.

Test facilities

Another fast-growing Texas control baby is Shaw & Estes, which specializes in instrumented test facilities for jet and rocket engines for the military. To the industrial field, the company supplies engine test stands, and instrumentation and control for oil refineries. Just recently it started designing nuclear instrumentation and building controls for electric power stations. In 1956, 11 years after it started, S&E's sales passed $5 million and its military backlog reached $11 million.

Then there is Varo Mfg. Co., located just north of Dallas, which has built up a $6-million annual business applying electronic controls to power conversion equipment. And the Texas Div. of Collins Radio, which has carried out extensive R&D work on airborne navigation equipment and commercial airborne weather radar.





solving logical problems with Burroughs pulse control systems

a one flip-flop serial binary adder

. . . conceived and proved in the same day

This new and unique serial binary adder will find many uses in digital work. But it might never have been developed without Burroughs Pulse Control Equipment to act as a catalyst for the engineer's imagination.

The engineer who developed the adder, like all others in logical design, is constantly faced with the problem of finding new components which require a certain amount of experiment and imagination. He is most efficient when using equipment that is as flexible as the problem and capable of keeping pace with his thinking. In this case, for example, his problem was reduced to: (1) setting down the idea in block diagram form, (2) interconnecting his Burroughs units accordingly, and (3) checking results.

His original idea was quickly brought to working reality, because a Burroughs System eliminates many of the usual steps in between. And while setting down the diagram for the system hook-up, he was automatically specifying not only the equipment he would ultimately need to build the unit, but also how to assemble it. Thus, he did away with breadboard hardware entirely.

You can give yourself the same creative edge by letting a Burroughs Pulse Control System give your imagination a chance to work. Just send us your pulse problem, and we'll gladly work out a Burroughs Pulse Control solution . . . at no cost. Or, write for Bulletin 236.

tools for engineers

Burroughs

BURROUGHS CORP. • ELECTRONIC INSTRUMENTS DIV.
Department A • 1209 Vine Street • Philadelphia 7, Penna.

Control ENGINEERING
JULY 1957

You CAN buy performance

When you purchase a control system component or an entire system, you are buying performance. While initially you think in terms of the vendor's application know-how, delivery schedules, and equipment operation, you are really after improvement in the performance of a machine, plant, or weapon. If you are not confident that the purchase will eventually produce this result, better cancel the order.

How can you determine the potential performance you buy? Three methods are available to you today:

- rely on the vendor for "free" analysis and recommendations
- operate your own systems engineering group
- let a contract for systems engineering services

Because there is a discernible swing from the long-standing first method to the other two within the heavy manufacturing and material processing industries, we think that you will be interested in the following table. It reports the gist of a survey conducted by Feedback Controls, Inc., of the market for systems engineering services in industrial control.

Status of Industrial Control Systems Engineering

Type of company or service rendered	Summary of individual attitudes	Major obstacles seen by persons interviewed
10 chemical manufacturers — 6 of major size 9 petroleum processors — 8 of major size	Great interest among instrument engineers and the several fully competent systems engineering groups; little interest or understanding from purchasing and manufacturing	Lack knowledge of process dynamics; measuring elements limit; no time available for systems design; process instrumentation in hands of contractor; must sell management; not economic
7 equipment contractors — 5 of major size	Interest displayed only in R&D	No funds available from clients for full systems engineering
3 process contractors	Considerable interest but recognize there is much to learn about techniques	Prefer to use members of own organization, rather than to buy service
7 other manufacturers (steel, glass, etc.) — 6 of major size	Great interest but little understanding of techniques	No obstacles
Power plant designers — 3 nuclear, 1 conventional	Considerable interest and understanding	No obstacles
Airframe and engine (test facilities)	Procedures of systems engineering well-established and recognized.	

In addition to probing a market the survey documents the status of industrial control systems engineering. It spots roadblocks. And it reveals the great interest you have in accurately assessing system performance. You can buy performance before laying out dollars for hardware. Pick your method.

THE EDITORS

12 different -hp- oscillators

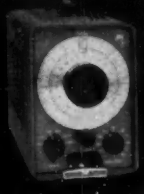
highest quality, outstanding value

complete coverage 0.008 cps to 10 MC

each designed to do a specific job best

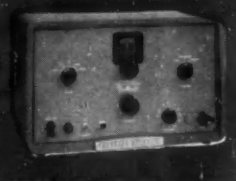
stable RC circuit pioneered by -hp-

201C—designed for high quality audio tests. Covers 20 cps to 20 KC. Output 3 watts/42.5 volts. $225.00

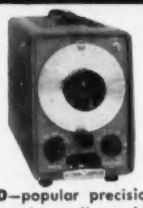


200J—extreme accuracy for interpolation and frequency measurements. Covers 6 cps to 6 KC, output 160 mw/10 volts; 20 volts open circuit. $275.00

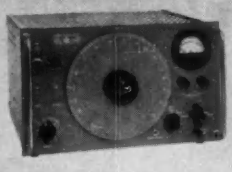
202C—replaces famous 202B for low frequency measurements. 1 cps to 100 KC. Output 160 mw/10 volts; 20 volts open circuit. $300.00



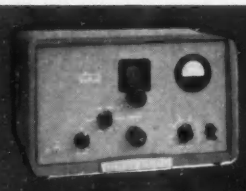
202A—for vibration analysis, servo tests, other vlf measurements. 0.008 to 1,200 cps. Output 20 mw/10 volts. $465.00



200CD—popular precision instrument for audio and ultrasonic tests. 5 cps to 600 KC; output 160 mw/10 volts; 20 volts open circuit. $160.00

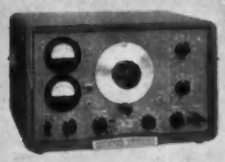


233A—carrier test oscillator covering frequencies 50 cps to 500 KC. Output 3 watts/600 ohms. $475.00



650A—highly stable, wide band; 10 cps to 10 MC. For audio, supersonic, video, rf measurements. Output 15 mw/3 volts. Frequency response flat ± 1 db. $490.00

200AB—for audio tests, 20 cps to 40 KC. Output 1 watt/24.5 volts. Simple to use, compact, rugged. $130.00



205AG—time-tested convenience for high power tests, gain measurements. 20 cps to 20 KC, 5 watts output. $440.00

206A—widely-used for high quality, high accuracy audio tests. Very low distortion. Covers 20 cps to 20 KC; output + 15 dbm. $565.00

200T—custom-engineered for telemetry, carrier current tests. 250 cps to 100 KC, output 160 mw/10 volts; 20 volts open circuit. $350.00

207A—low cost sweep oscillator, continuous output 20 cps to 20 KC, flat response, low distortion. May be motor driven, or coupled to recorder. $275.00

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Transmitting Data by Light Modulation

Wide-band modulation of light—visible, infrared, or ultraviolet—has been made possible by photoelastic modulation. The advantages to the military are obvious: wireless control or communication without danger of detection or jamming, plus radio silence. Reliable wireless data links open up many possibilities for industrial applications, too. And this one also offers truly private communication. The limitation is the need for a real line-of-sight path. The new technique* permits modulation of very strong light beams, however, so that transmissions over 10 or 20 miles or more are practical.

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Radio communication links have two characteristics that poorly equip them for certain military control problems: they are easily detected by monitoring devices, hence can jeopardize an entire operation; and they can usually be "jammed", as by high-energy noise transmission at the frequencies concerned. Wireless data transmission is very necessary, however, not only for communications between personnel, but also for data telemetering between aircraft and missiles and ground stations. A transmission link that is almost impossible to detect and jam might represent the difference between success and failure for a military mission.

A new method of modulating a beam of light has made possible a transmission technique that is nearly invulnerable to detection or jamming. Of course the use of light as a carrier, rather than radio-frequency electromagnetic waves, definitely limits this technique to line-of-sight distances. But this is usually not a disadvantage for control applications, though it may be for personnel communications.

Earlier methods of light modulation made use of a Kerr cell, in which a dielectric fluid subjected to a strong electric field acts as a light polarizer. Illuminated from one side with polarized light and viewed from the other side through a Polaroid analyzer, the Kerr cell acts as a light valve. The Faraday effect, by which particles in colloidal suspension are caused to line up by a magnetic field, can be used similarly, as can small birefringent crystals. All of these techniques are limited to rather small sizes by the basic nature of the cell or crystal or the difficulties of producing strong electric or magnetic fields over large areas. Practical cells may be only 2 to 3 in. in diameter. These small sizes severely limit the amount of light passed without excessive heating, and thus the maximum range over which the light may be used as a communications carrier.

The new method permits successful modulation of any size light source up to the largest needed for line-of-sight transmission. Essentially, the technique involves the propagation of ultrasonic pressure waves in a transparent plate placed in front of the light source. The pressure waves are induced in the plate by quartz crystals cemented along one edge and driven by an RF amplifier (see Figure 1). The size of the plate and the frequency of the pressure wave

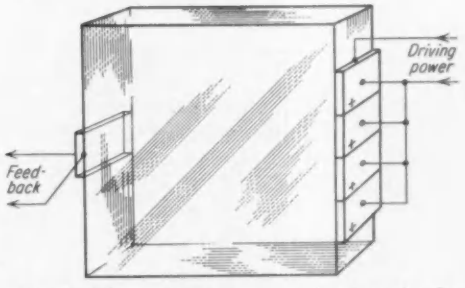


FIG. 1. Ultrasonic pressure wave is set up in glass block by crystals bonded to (right) edge. Feedback crystal controls frequency of ultrasonic driving source.

* United States Letters Patent of Robert A. Rines and Hans Mueller, Nos. 2,622,470–2,623,165, and 2,707,749.

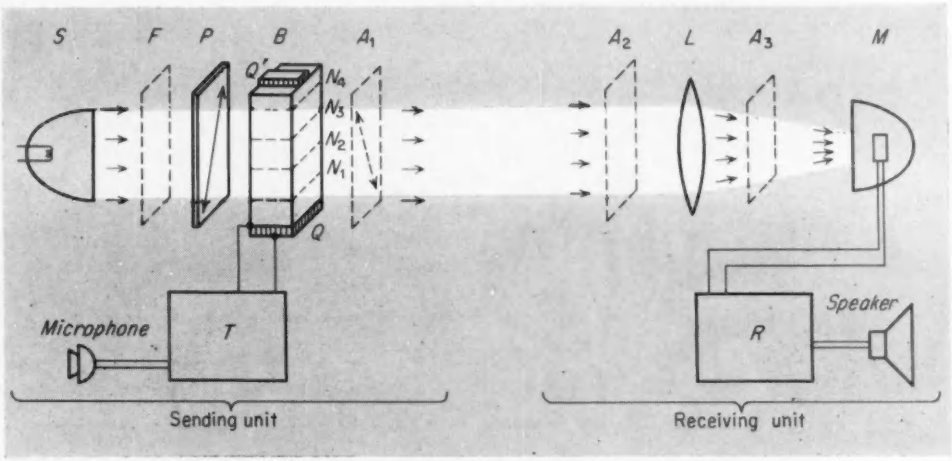


FIG. 2. Complete sending and receiving system. Operation is explained in text.

are such that the plate is many wavelengths long.

MODULATION TECHNIQUES

The frequency of the ultrasonic source is adjusted to produce a standing pressure wave in the glass plate. This standing wave has nodes of zero pressure between which the pressure varies from maximum tension to maximum compression at the ultrasonic driving frequency. Due to photoelastic effects, tension changes plane-polarized incident light into right elliptically polarized light, and compression changes it to left elliptically polarized light. Therefore, referring to Figure 2, if a light source S is plane-polarized by polarizer P at 45 deg to the nodal lines in the block, and viewed through Polaroid analyzer A_1 at minus 45 deg, no light will be transmitted at the nodal lines. The depolarization of the light by the stresses between the nodal lines, however, produces a fraction at minus 45 deg. Since both tension and compression lead to transmission, the intensity of the light reaching the receiver is modulated at twice the frequency of the ultrasonic carrier. This is the first of the four types of modulation illustrated by Figure 3. The nodes (dark) and antinodes are clearly visible when viewed through A_1, as in the photograph of Figure 4.

Removing the analyzer from the transmitter and placing it before the photocell of the receiver at A_2 produces the modulation shown in Figure 3B. In this case, the light reaching the receiver is an incoherent mixture of right and left elliptically polarized light from the various parts of the area of the block. This incoherent mixture is a depolarization-modulated beam.

To arrive at communication of type C or D in Figure 3, the polaroid P is cut into strips of a width equal to the distance between the ultrasonic nodes. Alternate strips are turned by 90 deg so that they produce plane polarization at plus 45 deg and minus 45 deg to the nodes. In this case, the entire area of the block emits right elliptically polarized light during one half-cycle of the vibration and left elliptically polarized light during the next half-cycle. To transform this into intensity modulation at the carrier frequency, a quarterwave plate must be inserted be-

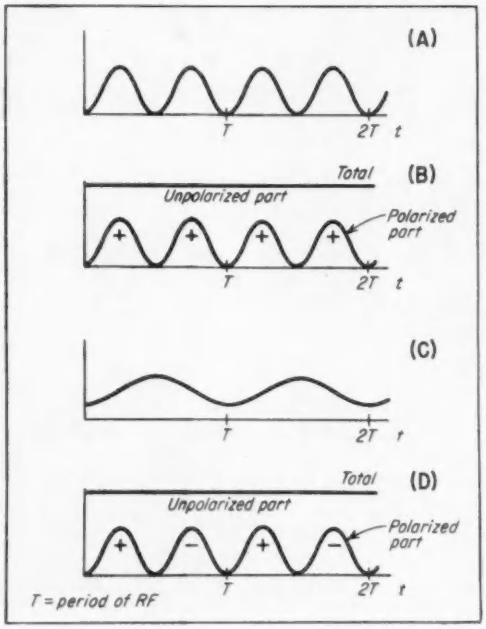


FIG. 3. Types of modulation possible:

A. Intensity or flux modulation at the doubled frequency of the exciting RF carrier.

B. Depolarization modulation at the doubled frequency. This implies that the light reaching the receiver is a mixture of unpolarized and polarized light in which the mixing ratio of the two parts varies periodically with the doubled frequency of the RF carrier.

C. Intensity modulation at the carrier frequency.

D. Coherency modulation with the frequency of the RF carrier. "Coherency modulation" refers to a beam made up of an unpolarized and a polarized part. The total intensity of the beam remains constant and the mixing ratio is modulated. It differs from "depolarization modulation" in that the type of polarization of the polarized part does not remain fixed (e.g., either linear horizontal, or linear vertical, or circular), but changes by switching to its opposite type (from horizontal to vertical linear, or from right-circular to left-circular) after every half-cycle of the RF variation.

tween the block B and A_1, so that the combination of the quarterwave plate and A_1 form a circular analyzer. Shifting this combination from the sender to the receiver produces transmission of type D.

The optical systems of type C and D provide stronger modulation than those of type A and B. For identical operating conditions, they double the communication range of the instrument. Type D is of special interest because it provides communication which cannot be intercepted or jammed by any known means. The light reaching the receiver is partially circularly polarized, with the polarized part changing periodically from right to left circular. Other light sources or sunlight have no effect on the reception and no other methods are known for creating this type of coherency modulated beams.

In each of the four types of modulation, the amplitude of the ultrasonic carrier modulation can be modulated by audio or control signals. This double modulation is illustrated by Figures 5 and 6.

Details of the block

Consider a glass plate, 1 to 2 in. thick and, say, 6 in. sq with quartz crystals cemented along one edge, as in Figure 1. For small plate sizes, a single crystal may suffice, but several are generally necessary for plates larger than 3 or so inches. The crystals are cemented to the plate by a special soldering process to obtain as rigid a bond as possible. Because of its natural mode of vibration, each crystal vibrates with largest amplitude at its center, and it has been found that energy is transferred to the plate most efficiently if the polarization of adjacent crystals is the same. To simplify wiring of the X-cut crystals, they are cemented with their optical axes in the same direction, and then simply connected in parallel electrically.

The plate should be good quality glass of low refractive index (1.50-1.55), or fused quartz. Ordinary plate glass is suitable, but crown or borosilicate glass of optical quality is preferable. Fused quartz is suitable only for cw communication because its high mechanical Q filters out the sidebands due to modulation. Thickness should be 0.5 in. to 2 in. Transmitting area is unlimited. Blocks with areas from 1 x 1 to 12 x 12 in. have been tested. The blocks of large area permit the modulation of extremely strong light beams. The upper limit is set by heating effects which can be suppressed by air cooling of polarizers and block.

The Q of the driving crystals is lowered by the load imposed by the glass plate. This reduces the sharpness of tuning and permits the system to be tuned to an odd multiple of the half-wavelength of the acoustic resonant frequency of the glass plate. This tuning produces an ultrasonic standing wave in the glass, Figure 4.

Referring to Figure 1, the reflecting (left) edge of the plate must be at an antinode to maintain a standing pressure wave. The frequency of the driving source oscillator can therefore be controlled by feedback from a crystal cemented to the reflecting edge and connected in a circuit to sense maximum output.

Because the maintenance of a standing wave requires reflection, the transmitting and reflecting edges of the plate must be ground parallel and polished. There is an interfering mechanism due to the Poisson effect, by which any solid that changes length (elastically) on one axis must also change length (usually oppositely) on another axis in order to preserve the volume-density product (mass). If the plate were exactly square, pressure-standing waves would also appear between the top and bottom edges of the plate due to Poisson vibrations. Since these Poisson waves would interfere with reception of the intelligence present on the original wave, the vertical length of the plate is made slightly shorter (or longer) than the horizontal length.

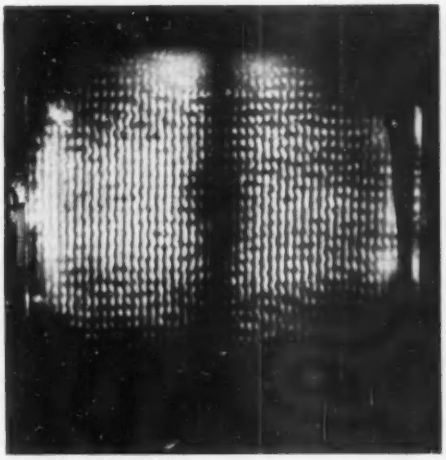


FIG. 4. Photograph of Type A modulation looking at light source through analyzer at A_1 in Figure 2.

Ultrasonic source

The frequency of operation can vary widely for any given size block. For example, for a 6-in.-sq block, there is a standing-wave frequency in every 0.1 megacycle range from 300 kc. to 10 Mc., and any of these can be used. The optimum frequency depends on the ratio of the lengths of the sides, and produces the least cross-modulation. The driving crystal resonance should be chosen close to this frequency. The block in Figure 4 is a 6-in. block, driven at about 0.9 Mc. For transmission of type C and D, only frequencies below 1 Mc. are practical because of the difficulties in making the polarizers.

Glass blocks require a driving power of only about ½ watt per cubic inch of glass, so that communications over 10-20 miles and more can be achieved

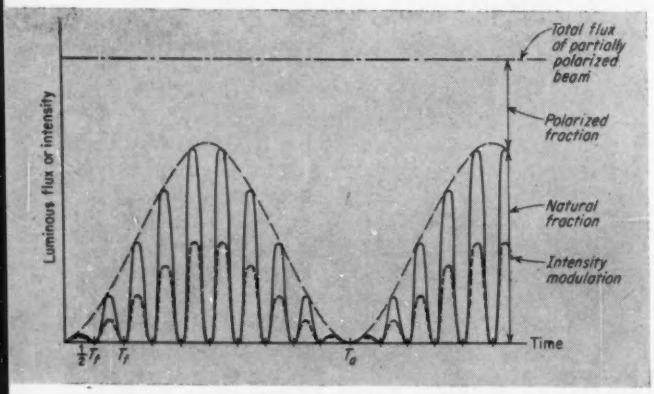


FIG. 5. Amplitude-modulated carrier of Type A. T_f is period of ultrasonic carrier; T_a is period of amplitude modulation.

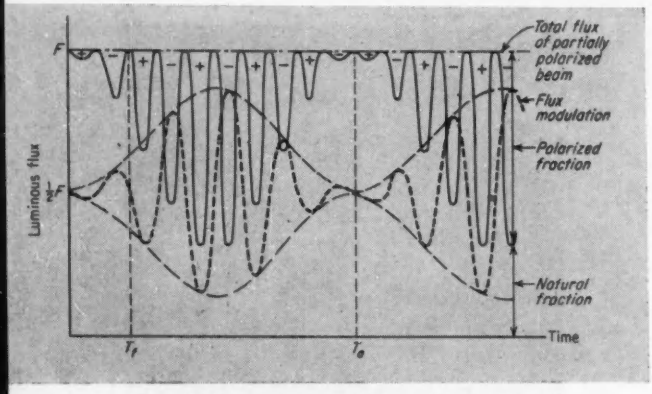


FIG. 6. Coherency-modulated carrier of Type D. Note that flux modulation is twice that in Figure 5.

with a 50-watt transmitter and a 6- to 8-in. block. Quartz blocks require only 0.01 watt/cu in.

The receiver

The receiver is a photoelectric cell. For transmission of types *A* or *B*, the audio signal can be received by using a gas-filled photocell or a resistance photocell, the latter coupled to an audio amplifier or, by means of a photo-multiplier, attached over a tuned circuit to the antenna circuit of an RF receiver. The transmissions of type *C* and *D* can be received only by the latter method. For types *B* and *D* suitable polarizers are inserted before the receiver to transform the depolarization or coherency modulation into flux modulation.

Light source

The photoelastic modulator can be adapted to any source and for any kind of light (infrared, visible, or ultraviolet) which is transmitted through glass or fused quartz and for which polarizers and quarter-wave plates are available. It can be used for a collimated beam for communication with a single receiver or for beams of large angular aperture. By using a cylindrical block surrounding the source, it can be developed for communication in all directions.

Test results

Tests so far have used as a source an airplane landing light, and a light filter transmitting the near infrared range of wavelength from 8,500 to 10,000 A. Block areas have been 6 by 6 in. or 8 by 8 in. Block thickness has been 1 or 2 in. The carrier frequency was 0.9 Mc. for type *B* transmission, and 0.35 Mc. for type *D*. Transmission was found to be consistently reliable for 4 miles with type *B*, and up to 7 miles with type *D*. In these tests no attempt was made to focus the beams.

A pilot model for two-way voice communication from ship to shore with the same type of light sources and blocks was successfully tested over distances up to 3 miles in stormy weather (40-mile gale). In these tests, spread lenses created beams with a horizontal aperture of 30 deg and vertical aperture of 30 deg.

APPLICATIONS

As was said at the beginning of this article, photoelastic light modulation has obvious advantages for the military, where radio silence must be preserved, and where resistance to jamming is needed. The RF source needed to drive the block is easily shielded so that it cannot be detected at distances over 100 ft. Though the light source is easily detected, even if infrared, the modulation is difficult to detect, even if it is suspected. This is because there are two variables, carrier frequency and polarizer angle, and both must be correct at the receiver to detect the modulation. Transmissions of types *C* and *D* also require a special polarizer at the receiver which must be changed if the frequency is changed. Jamming is virtually impossible for types *C* and *D*.

Industrial and civilian applications include all data-communication problems where line-of-sight contact is normal but wire connections are impractical. Light modulation can be used without FCC restrictions, since it does not use valuable space in the radio bands. At airports it can provide many more non-interfering communications channels (for automatic landing systems, for example) and ground-control channels without using already-jammed radio bands.

The Civil Aeronautics Administration is presently considering a proposal that the rotating beacons on the top and bottom of all aircraft be modulated by this technique. A receiver in each plane would then provide a proximity warning device that could significantly reduce the probability of collisions.

A factory application might be communication with or control of a trolley crane that may move a thousand feet or more down a steel mill bay. Dirt and corrosive environment make trolley wires noisy, resulting in poor communication and erratic control. Several control signals could easily be multiplexed with the voice channel on an infrared light beam.

Selecting Loops for Critical Control

THE GIST: Before the engineer can specify control equipment for a particular system he must first decide:

1. **How many properties must be controlled;**
2. **What variables must be manipulated.**

Most methods for solving these preliminary problems represent two extremes. On the one hand, cut-and-try methods, involving guesswork, often result in an incompletely-controlled system; on the other hand, the degrees-of-freedom approach is likely to be incorrectly applied and result in too many control loops being specified. The method presented here eliminates the guesswork of the former and simplifies the latter, yet results in a system which is neither overcontrolled nor uncontrolled.

A. H. McKINNEY, Instrument Engineer, Chester, Pa.

In designing a control system for an industrial process, one of the first problems is to select appropriate control loops. This amounts to pairing properties to be controlled with variables that can be manipulated to best effect the control. At the same time, the engineer must determine the exact number of loops required. If too few loops are used, the system will not be critically controlled and properties not directly controlled may be free to wander. If control of too many loops is attempted, it may be impossible to hold one or more of the measurements at set-point values.

Figure 1 illustrates the problem. The process shown here might be a simple mixing operation or chemical reaction. The variables which can be manipulated are represented by the valves 1, 2, 3, and 4. Properties that can be measured and controlled are represented by the instruments *A* through *F*. If a single loop is closed by connecting controller *A* to valve 1, (as indicated by the broken line) the particular property represented by *A* should be constant. In the same way, controller *B* could be connected to valve 2, *C* to valve 3, etc. As will be seen later, the critical number of control loops for this system is three. Prior to closing the third loop, the uncontrolled properties *C*, *D*, *E*, and *F* may vary. On closing the third loop, however, the remaining properties *D*, *E*, and *F* will be fixed without being directly controlled. This is because several properties are mutually dependent upon the same variable. This relationship permits indirect control of an essential property which, because of difficulty or high instrument cost, is impractical to control directly. An orderly procedure for establishing critical control will be demonstrated in the following pages.

PROCEDURE

Consider simple controlled systems, those that cannot be further separated into systems which are themselves controlled. Such systems are critically controlled when the following equations are satisfied:

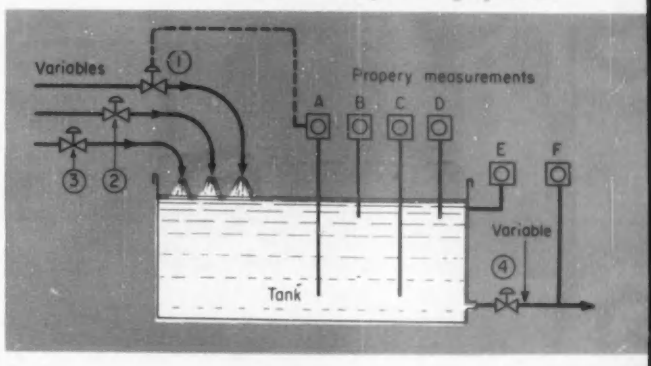
$$P_c = V - 1 = Q + A \text{ and} \quad (1)$$

$$A = J \quad (2)$$

Equation 1 states that the *number of properties* (P_c) used for the critical control of a simple system will be *one less* than the *number of externally connected variables* (V) affecting the process. It further states that this number equals the number of *qualitative* properties (Q) plus the number of inventory, or *quantitative*, properties (A). Equation 2 says that the number of inventory properties equals the number of externally connected junctions (J).

The variables to be controlled must be dominated by measurements or intelligence generated from within the system. The one variable not manipulated by the system may be uncontrolled (wild), or manipulated by some intelligence external to the system. A step-by-step procedure for best satisfying these equations follows:

FIG. 1. Simple mixing operation.



STEPS	APPLICATION TO DISTILLATION COLUMN IN FIGURE 3

Step 1. Describe the purpose of operating the system by listing the minimum number of *essential* properties: those that will adequately specify the end product or process result.

Step 2. List the variables that influence these essential properties. This total is V.

Step 3. List a number of related properties, particularly those that can be measured more cheaply and reliably than the essential ones in Step 1. The number of properties listed in Steps 1 and 3 must total at least V — 1.

Step 4. Construct a *variables-properties* chart as shown in Figure 2, and insert *figures of merit* at each intersection of a row and a column.

Step 5. Select the one variable that the system is not to manipulate.

Step 6. Select optimum combination of variables and properties. Selection of a particular row and column closes a control loop. Be sure that properties have been selected for which reliable measuring instruments are available, and check to see that Equation 2 has been satisfied.

Area of interest

Step 1, listing essential properties of the operation, may have only one or two entries. Typically, the purpose of the system is to produce material of a desired quality, which can frequently be described by a single physical measurement. The fact that no instrument may be available to measure this essential property may be only a minor inconvenience. Since this analysis could be applied to sewage disposal, electrical circuits, or color control, Step 1 serves the purpose of defining a limited area of interest, and makes it possible, in Step 2, to reduce the number of variables acting on the system.

Listing variables and related properties

Step 2 enumerates the externally-connected sources of material or energy which influence at least one of the essential properties listed in Step 1. These variables must furthermore be different in some respect that is recognized by at least one of the instruments finally selected to control the system.

The word *variable*, as used here, describes a flow of material or energy that does not necessarily vary. It may be constant. To be listed as a variable it is only necessary that, if it did change, one or more of the measuring instruments used would be affected. Heat loss from a system is an example.

For purposes of this discussion, the properties listed in Step 3 are termed *related properties*, not because they are like the essential properties, but rather because they are influenced by the same variables. They should actually be as unlike as possible. Thus density and index of refraction are likely to be duplicates of the same quality information.

Related properties selected should be influenced only by those variables included in Step 2. For instance, if barometric pressure had no effect on the essential properties, it would be unwise to list boiling point as a related property. Listing boiling point would require the addition of pressure to the variables of Step 2, and an additional control loop.

Figures of merit

At each intersection of a row and column on the variables-properties chart (Figure 2), a figure of merit is inserted. These values indicate the relative response of each possible control loop. Based principally on judgment and experience, they answer the question: "If this particular loop were established and stabilized on manual control, what would

FIG. 2. Sample variables-properties chart with figures of merit inserted.

Properties	Variables 1	2	3	4	5
A	F	P	G	G	P
B	N	G	F	P	P
C					
D					
E					
F	P				F
G	G	F	P	G	P
H	F	F	P	P	G

Letter indicates response characteristics
G - good F - fair
P - poor N - nil

DEFINITIONS

CRITICAL CONTROL—A system is critically controlled if it is impossible to obtain a sustained deviation in the measurement of an essential property, not directly controlled, without the eventual appearance of a sustained deviation in one or more directly controlled properties.

FIGURE OF MERIT—A value that indicates the static and dynamic behavior of a particular control loop. No absolute accuracy is required for such values so long as they are accurate relative to the values assigned all other control loops.

JUNCTION—A point at which three or more flow streams meet. One enters, one leaves, and the third may enter or leave.

PROPERTY—An internal condition or aspect of a process that can be measured and expressed as a numerical value. Properties may be either qualitative or quantitative.

RELATED PROPERTY—Two properties are related if they are both dependent on the same variable for their determination.

VARIABLE—As used in this article, the term variable refers exclusively to a condition or aspect of any stream externally connected to a simple system, including the internal streams of a complex system. Two or more such conditions, indistinguishable by at least one instrument used to control the system, must be considered as a single variable.

STEPS	APPLICATION TO DISTILLATION COLUMN IN FIGURE 3
(1) LIST ESSENTIAL PROPERTIES	The property which best specifies the desired result is (*a*), Composition of Heads Product.
(2) LIST EXTERNALLY CONNECTED VARIABLES	The variables involved are flows: **1**, Feed; **2**, Heads Product; **3**, Cooling Water; **4**, Steam; **5**, Tails or Bottoms Product.
(3) LIST ADDITIONAL (RELATED) PROPERTIES	Properties related to the essential property are: (*b*), Vapor Pressure; (*c*), Top Temperature; (*d*), Bottom Temperature; (*e*) Differential Pressure; (*f*), Reboiler Level; (*g*), Composition Tails.
(4) CONSTRUCT VARIABLES–PROPERTIES TABLE AND INSERT FIGURES OF MERIT BASED ON SOUND JUDGEMENT, ETC.	The Variables-Properties table (inset here for convenience) contains Figures of Merit represented as follows: *G* = Good *P* = Poor *F* = Fair *N* = Nil
(5) SELECT ONE VARIABLE TO BE UNCONTROLLED BY THE SYSTEM	Variable **1**, Feed, is selected for two reasons: (1) There are no "*G*" values in this column. (2) The Production rate can then be set manually as desired. Line through column **1** indicates this variable will not be controlled.
(6) SELECT (*n*–1) FIGURES OF MERIT, EACH FROM A DIFFERENT ROW AND COLUMN. TOTAL MUST BE A MAXIMUM (ALL "*G*" VALUES IF POSSIBLE) EQUATION 2 MUST BE SATISFIED	Lines through rows (*a*) and (*g*) indicate these properties are eliminated as composition measurements, too costly to control directly. Selections are made from the shaded squares as there are sufficient "*G*" values for the solution. Loop **5**-(*f*) is selected, the product of the only "*G*" value in column **5**. Obviously loops **2**-(*c*) and **3**-(*b*) must also be selected. The fourth loop may be either **4**-(*d*) or **4**-(*e*) as both have "*G*" values. For economy loop **4**-(*d*) is chosen.

PROPERTIES	VARIABLES 1	2	3	4	5
(*a*) Composition Heads Product	*P*	*G*	*G*	*P*	*P*
(*b*) Vapor Pressure	*F*	*F*	*G*	*G*	*P*
(*c*) Top Temperature	*F*	*G*	*G*	*F*	*P*
(*d*) Bottom Temperature	*F*	*P*	*P*	*G*	*F*
(*e*) Differential Pressure	*P*	*P*	*P*	*G*	*F*
(*f*) Reboiler Level	*F*	*G*	*F*	*G*	*G*
(*g*) Composition Tails Product	*P*	*P*	*P*	*F*	*F*

be the response of the measured property to a slight step change in the corresponding variable?" High figures of merit indicate that response is:

- Prompt
- Large
- Proportional to the valve motion
- Quick to stabilize at a new value

No single objective number can summarize the data involving frequency response, system sensitivity, and self-regulation to characterize both static and dynamic responses. Perhaps two numbers involving sensitivity and response time will eventually be used. At the moment, however, only subjective ratings are possible. Fortunately, the values used need be accurate only with respect to each other; they require no absolute precision.

Uncontrolled variable

In some systems it may be possible to control all of the variables by available means. If so, a free choice exists as to which is not to be controlled by information from within the system. This might be the main flow of raw material to the process, or flow of product from the process; in either case it would be used to set the production rate. With a critically controlled system, it should be possible to have different production rates and still maintain product quality and operating conditions.

In other systems, one variable may be less controllable or even uncontrollable. Obviously this becomes the variable selected for noncontrol. As will be seen in the case of a rotary kiln, it is the heat loss to the outside that is uncontrollable, since it is not feasible to provide variable insulation.

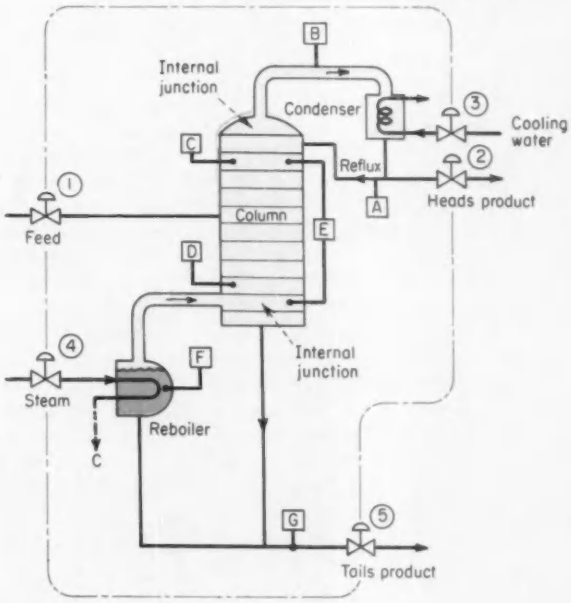
Optimum arrangement and junctions

V—1 variables with the best figures of merit are selected from the table to provide the optimum total. For a table consisting of N variables and M measurements, the total possible arrangements is:

$$\frac{M!}{(M-N+1)!}$$

In some cases, there may be several alternate selections giving equally high sums for the V — 1 figures

FIG. 3. Typical distillation process.



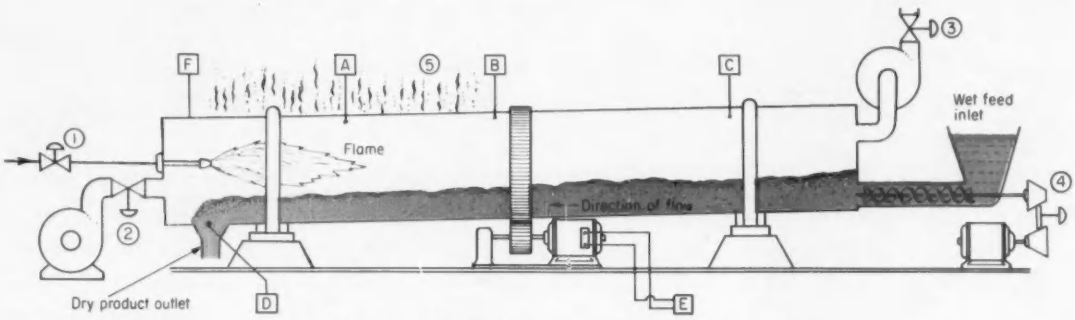


FIG. 4. Single shell rotary kiln for drying or calcining operation.

		Variables				
		Fuel oil	Forced draft damper	Induced draft damper	Feed rate	Heat loss
Properties	Dry prod comp	G	F	F	F	N
	T#1	G	G	G	P	P
	T#2	G	G	G	F	F
	T#3	P	P	P	F	G
	Power	N	N	N	G	N
	Pressure	P	G	G	N	N

FIG. 5. Variables-properties table for establishing critical control of rotary kiln.

of merit chosen. This agrees with experience; there are numerous arguments supporting different arrangements for the control of a particular process. It will require better figures of merit than are now available to isolate a single arrangement as the optimum in all cases.

The last part of Step 6, satisfying Equation 2, requires an inventory controller for each junction. A junction may be a tank as in Figure 1, or a branch in the pipe line. In any continuous process everything that goes in must come out, but frequently suitable control is required to make sure that this axiom does not produce undesirable effects. In Figure 1, for example, without a level controller excess material might simply overflow the tank.

An inventory controller, while necessary for system operation, contributes only to the stability of production rates. The quality controllers, on the other hand, are the real measures of system flexibility.

Weight and level are usually, but not necessarily, inventory measurements. Similarly, density, pH, and index of refraction are normally measures of quality. Two obvious exceptions are:

- the weight of a controlled volume of liquid would provide a measure of density.
- measurement of gas density in a controlled volume would be an inventory measurement.

The distinction between quality and quantity measurements may be even more subtle. If the pressure at the top of a distillation column is controlled, the top temperature is a quality measurement. Conversely, if temperature is controlled, pressure becomes a quality measurement. There can be only one independent quality measurement, and in this case it is either temperature or pressure. The other necessarily becomes a measure of inventory. It makes no difference which one is the inventory property and which the quality property; controlling both satisfies the system and the equations. In Figure 1, where three streams enter and one leaves the tank, there must be one inventory and two quality controllers. With any other combination, the system would not be critically controlled.

An internal junction not requiring a valve in any of its branches need not be counted. Internal means that all branches terminate in other junctions within the system and none are externally connected. Figure 3 shows two such internal junctions.

SIMPLE SYSTEMS APPLICATIONS

The following examples use as figures of merit: none (N), poor (P), fair (F), and good (G). These are the qualitative expressions of a single opinion. The examples illustrate the method—they do not necessarily represent the best possible solution for a specific installation.

Distillation column

The problem is to select the optimum arrangement of controllers connected to valves for the distillation column shown in Figure 3, using the procedure outlined above. One orderly approach is shown in the table on page 69. The procedure is repeated in the left-hand column, while the application of each step to the problem is illustrated in the right.

Notice that in the application of Step 2, heat loss is not considered a variable: no instrument can distinguish between actual heat loss and a slight increase in cooling-water temperature or flow.

The variables-properties chart of Step 4 is inserted in the table solely for convenience. Figures of merit assigned each loop are based on experience

with similar processes. Step 5, eliminating feed rate from the list of controlled variables, satisfies the first equation. In checking Equation 2 note that there are three externally-connected junctions, each requiring that an inventory property be controlled.

Reboiler level is obviously an inventory measurement, as is also either vapor pressure or top temperature, as explained earlier. It is equally clear that with fixed pressure and top temperature conditions, both the differential pressure and bottom temperature measure essentially the same thing, viz., the amount of vapor passing up the column. This also is an inventory measurement, and Equation 2 is therefore satisfied.

Rotary kiln

Another example of a simple system is the rotary kiln shown in Figure 4. This time the problem is critical control of a drying or calcining process.

Step 1. The property of greatest interest is *D*, composition of the final product.

Step 2. Variables which have an effect on this composition are:

(1) Fuel oil flow
(2) Forced draft damper position
(3) Induced draft damper position
(4) Feed rate
(5) Heat loss

Step 3. Related properties that could be used for critical control are:

(A) Front-end temperature, T_1
(B) Middle temperature, T_2
(C) Back temperature, T_3
(E) Power to driving gear
(F) Kiln gas pressure

Step 4. Figure 5 is the variables-properties array for this example with figures of merit inserted. These values are again based on operating experience and past performance.

Step 5. Variable 5, heat loss, is selected as the uncontrolled variable. There is nothing that can be done about heat loss on a continuous basis.

Step 6. Property *D*, the product analysis, is eliminated as too difficult. Figures of merit other than G are also eliminated. There remain only those selections indicated by the shaded area of Figure 5. Variable 4, feed rate, must be manipulated by the power measurement, *E*, for optimum control. This establishes one control loop. It now becomes evident that any combination of the three remaining properties and variables, except 1-*F*, gas pressure manipulating oil flow, will be equally satisfactory.

Equation 2 calls for two inventory loops, as junctions exist at either end of the kiln. Pressure is a measure of the gas-phase inventory within the kiln. Motor power reflects the solids loading. This leaves

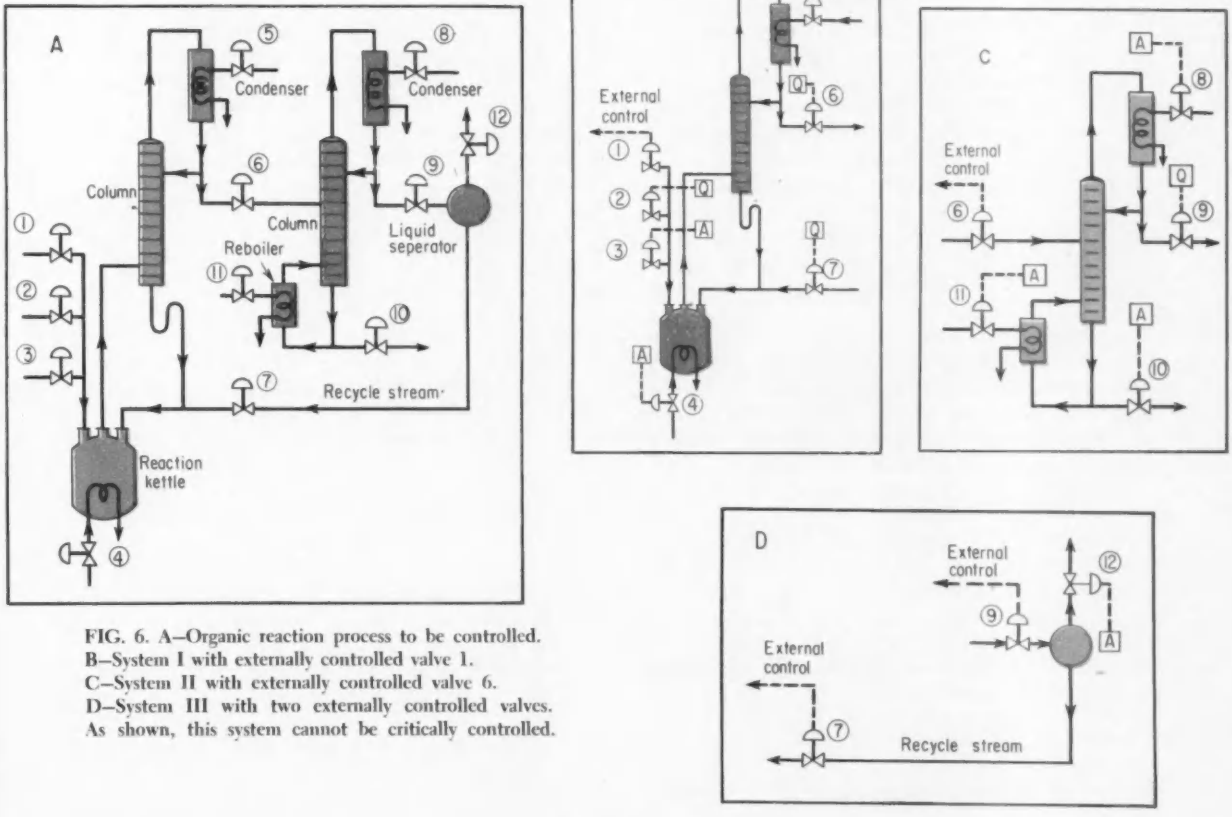


FIG. 6. A—Organic reaction process to be controlled.
B—System I with externally controlled valve 1.
C—System II with externally controlled valve 6.
D—System III with two externally controlled valves. As shown, this system cannot be critically controlled.

the two temperatures for quality control loops. This means that the product can be dried or can react to the desired maximum temperature, and that it can be brought up to this temperature at a controlled rate. For some products this thermal history has an independent effect on product quality.

COMPLEX SYSTEMS APPLICATIONS

The simple system shown in Figure 3 can be isolated as indicated by the broken line connecting the control valves. Such a system will have three characteristics:

- the isolating line can be made to connect all of the control valves;
- a control valve will exist in each of the process lines cut;
- The system cannot be further reduced to simpler control systems.

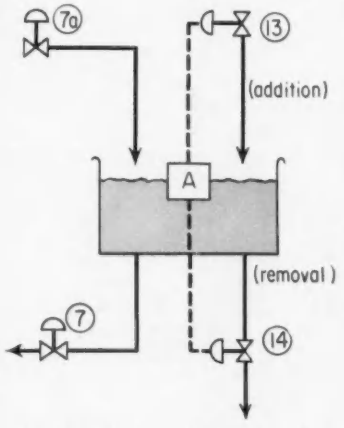


FIG. 7—Storage tank added becomes System IV. Establishing critical control of a distillation column.

Complex systems arise from the interconnection of two or more simple systems. Equations 1 and 2 apply equally well to a complex system, hence no more than one uncontrolled variable may be connected to the entire process. However, interconnecting streams present a problem.

Assume two simple systems, X and Y, connected by a valve, z. If valve z is controlled by measurements in system X, then to system Y, the stream appears to be uncontrolled. To satisfy Equation 1, system Y now cannot have any other externally-connected stream controlled by outside intelligence.

The following preliminary steps provide a way to separate complex systems into critically controlled simple systems:

(a) Select the one variable to be controlled by an intelligence external to the complex.

(b) Isolate the simple system to which the above variable is connected. Assign the required number of Q and A controllers to the remaining variables externally connected to this system.

(c) Isolate adjacent simple systems and assign Q and A controllers as above.

(d) Check that no internal stream is manipulated by more than one simple system and that Equations 1 and 2 are satisfied for each simple system.

(e) Apply the procedure previously demonstrated to produce an optimum arrangement for each of the simple controlled systems.

Example of procedure

The organic reaction process illustrated in Figure 6A is to be critically controlled. Preliminary steps are:

(a) The flow in stream 1 is selected as the one externally connected variable that is not manipulated by any intelligence within the complex system.

(b) System I is isolated as shown in Figure 6B. This system contains stream 1 selected for external operation. With seven variables and three junctions, three quality and three inventory controllers will be required. These may be arranged as shown.

(c) Figure 6C shows System II, the one adjacent to System I. Since valve 6 is already controlled by System I, the remaining valves must be dominated by System II. With three junctions, this system requires three inventory and one quality controllers. One possible arrangement is as shown.

Figure 6D shows the remaining system. Stream 7 was specified as controlled by System I, and stream 9 by System II. This produces an impossible situation, if System III is to be critically controlled.

(d) Had the above discrepancy not been noticed in step (c), it would have been picked up here when checking for duplicate control.

Discussion of complex systems

The difficulty that arose in this example was due to recycle stream 7. If there had been two such recycle streams, critical control might have been impossible. However, before considering means to overcome this difficulty, it is appropriate to establish that the apparent excess number of variables is real. Suppose, in Figure 6, that recycle stream 7 is the same as one of the feed streams, e.g., stream 2. Then streams 2 and 7 constitute a single variable and if the flow in stream 7 is insufficient to satisfy the controller connected to valve 2, stream 7 can be controlled by System III and System I can still function as shown in Figure 6B.

If a recycle stream connecting two simple systems is detectably different from the streams of both systems as determined by control instruments operating in both systems, then one solution is given in Figure 7. Flow stream 7 of Figure 6A is broken by the insertion of a storage tank. Stream 7a can be dominated by System III and stream 7 by System I. The tank itself becomes System IV. It will be necessary to add (stream 13) or remove (stream 14) material to keep the process in balance. In this way it will be possible to set the production rate at desired values. An alternate would be to allow the inventory controller, "A", in Figure 10, to control valve 1 of Figure 6B. Now it will not be necessary to add or remove recycle material. In this case, however, the process will establish its own production rate which the operator will not be free to change without upsetting one or more of the quality measurements.

How to Estimate the Resonant Frequency of Hydraulic Actuators

B. C. MOORE, Douglas Aircraft Co., Inc.

Determining the resonant frequency of a hydraulic actuator is the starting point in the design of many systems. Because the resonant frequency establishes the frequency at which the Nyquist plot must be closed, it influences the design of all parts of the system. An estimate is therefore a key factor in competent system design.

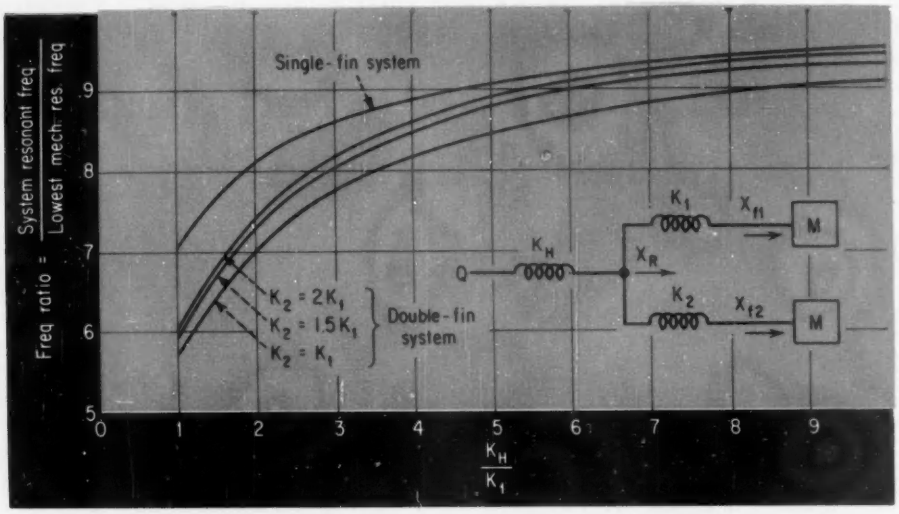
Valve characteristics, distributed mechanical stiffness, inertia, friction, and backlash complicate exact analysis of a complex mechanical-hydraulic actuating system. Because differential equations written for this analysis can include tenth- and higher-order derivatives, accurately calculating the resonant frequency of the entire system is a job for analytical specialists or for an analog or digital differential analyzer.

But when the control engineer is looking for approximate answers during his first evaluation of a mechanical-hydraulic system, and when tolerances on parts cause variation between systems produced, shortcut calculations such as the one set out here are justified. The graphs presented give rapid answers for specific configurations and show up the effects of changes in the mechanical and hydraulic components. The author has applied his method to over 50 different setups for which the system resonant frequencies had been measured and reports that the calculated frequencies were all within plus or minus 30 percent of the measured frequencies. Thirty tests made on one variation yielded an approximately Gaussian distribution with a range of plus or minus 30 percent and an average very close to the calculated value. This distribution sets the tolerance required in system design. It also suggests that more refined design analyses are not justified unless manufacturing methods can hold tighter tolerances.

Developed for rapid evaluation of multiple-shaft actuators for aircraft and missiles with multiple-fin control surfaces, the method is also applicable to mechanical-hydraulic actuators for machinery and valves.

See next page for equations, graph, and instructions for use of graph.

Simplified schematic model of double-shaft system



Q = flow at valve, gpm
K_H = hydraulic spring connecting valve to ram, lb/in.

$$= \frac{A_R^2 B}{V}$$

where A_R = ram area, in².
B = fluid compressibility, lb/in².
V = fluid volume of cylinder and tubing, in³.

K_1 = smaller shaft spring rate, lb/in.
K_2 = larger shaft spring rate, lb/in.
M = mass of only the driven member, lb sec²/in. (Inertias of shafts and actuators were ignored. It happened that both driven members had the same mass.)
X_R = ram displacement, in.
X_{f1} = smaller shaft displacement, in.
X_{f2} = larger shaft displacement, in.
ω_1 = resonant frequency of driven mass and smaller shaft, cps
ω_2 = resonant frequency of driven mass and larger shaft, cps

Mathematical model of double-shaft system

The mathematical model of the system shown schematically in the figure is:

$$\frac{X_R}{Q} = \frac{C}{sA_R} \times$$

$$\frac{\frac{1}{K_1K_2} - (K_1+s^2M)(K_2+s^2M)}{\left[1+s^2M\left(\frac{K_1+K_2}{K_1K_2}+\frac{2}{K_H}\right)+s^4M^2\left(\frac{K_1+K_2+K_H}{K_1K_2K_H}\right)\right]}$$

where s is the Laplace operator and C = 3.85 in.³/sec/gpm converts the units to in./gpm. For a single-shaft or single-fin system, the mathematical model simplifies to:

$$\frac{X_R}{Q} = \frac{C}{sA_R} \times \frac{1/K_1\,(K_1+s^2M)}{1+s^2M\left(\frac{K_1+K_H}{K_1K_H}\right)}$$

How to use graph to find overall system resonant frequency

The graph is a plot of the mathematical model solved in terms of the ratio of overall system resonant frequency to the lowest mechanical resonant frequency, ω_1, of the driven mass and the various driving shafts.

1. Calculate K_H, the hydraulic spring rate, and K_1, the spring rate of the least stiff shaft. Take their ratio, K_H/K_1.

2. Find the intersection of K_H/K_1 on the appropriate curve for a single-fin-and-shaft system, or for a multiple-fin-and-shaft system in which: $K_2 = K_1$, $1.5K_1$, or $2K_1$.

3. From the intersection determine the frequency ratio, FR. Calculate the lowest resonant frequency, $\omega_1 = (K_1/M)^{1/2}$, from the known driven mass, M, and the lowest shaft spring rate, K_1. Multiply ω_1 by FR. The result is the system resonant frequency.

CHROMATOGRAPHY

analyzes gas and vapor products in the plant

E. G. FELLOWS, Carbide & Carbon Chemicals Co.

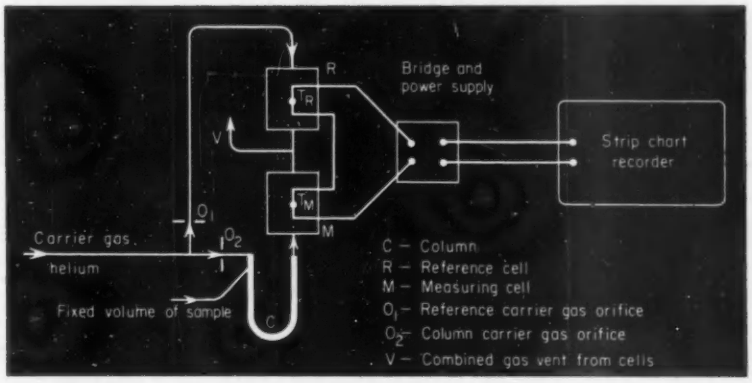


FIG. 1. Schematic showing basic components of a vapor-phase chromatographic analyzer: the column, the carrier gas system, the sample gas system, and the detector and recorder.

THE GIST: The technique of chromatography was developed about 50 years ago to separate and identify chemical components in a sample on the basis of the colors they exhibit. Although present-day chromatographic gas and vapor analyzers still separate and identify sample components, they no longer do it on the basis of color. Rather, gas and vapor samples are separated in a column, and a property of the gas mixture coming out of the column, such as thermal conductivity, is detected. The resulting signal is suitable for recording and possibly control.

Author Fellows presents, in this third article on analysis instrumentation, the basic concepts of a plant-type chromatographic analyzer, tells how it determines which components are present in the process stream, and how much of each. The article includes a description of chromatographic equipment and the attendant problems and their solutions in programming the analyzer for continuous duty in the plant.

CHROMATOGRAPHY BASICS

There are three generally-accepted systems of vapor-phase chromatography: frontal, displacement, and elution. In all of them a carrier gas forces the sample whose components are to be separated through a packed glass or metal column having a length to diameter ratio (l/d) which in practice varies from 25 to 3,000. The column is packed with an adsorbent or liquid-coated inert material (stationary phase) that separates the sample (mobile phase) into its components. Chromatographic columns have a separating efficiency approximating that of a distillation column with as many as 2,000 plates.

Elution systems

The elution system offers the greatest overall advantages in vapor-phase chromatography, particularly when instrumenting the technique for plant applications in monitoring and analyzing gas and vapor streams, and will be the only one discussed here; descriptions of frontal and displacement systems are found in the reference. The data obtained from an elution analysis are easily interpreted in quantitative and qualitative terms, and can be compared with reference data to correct deviations.

The elution system has two variations:

▶ gas-solid adsorption chromatography—in which the sample's adsorbed components are selectively desorbed and eluted by a carrier or stripper gas ac-

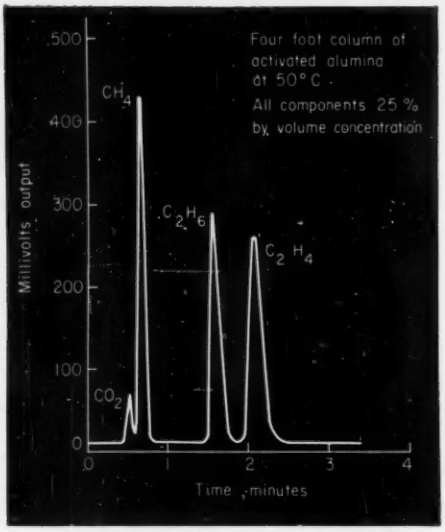


FIG. 2. Chromatogram of equal-percentage concentrations of ethane, methane, ethylene, and carbon dioxide in sample injected into column.

cording to their vapor pressures. Thus, each component emerges from the column admixed with the carrier gas as a measurable binary mixture.

▶ gas-liquid partition chromatography—in which the gas-sample components are dissolved by the liquid coating of the inert column packing material and subsequently eluted selectively by the carrier gas according to their liquid partition coefficients (Henry's law). Again, each component emerges from the column admixed with the carrier gas as a measurable binary mixture.

HOW A CHROMATOGRAPH WORKS

A basic elution-system chromatograph is shown in Figure 1. The four major parts of this system are:

- the column for separating sample components
- the carrier gas equipment
- the sample gas equipment
- the detector and recorder for plotting component emergence with time

Each of these major parts will be discussed below. First, however, it might be worthwhile to see how the basic chromatographic system operates:

Assume a gas composed of equal volumes of carbon dioxide, methane, ethylene and ethane is to be quantitatively analyzed. In the system shown in Figure 1 the following events take place as the analysis proceeds: a controlled flow of carrier gas passes through orifice O_1 and the reference cell R at a typical rate of 3 ml/min; and a 60-ml/min controlled flow of carrier gas passes through orifice O_2, through column C, and through the measuring cell M. With no sample gas flowing, both the reference and measuring cells sense only carrier gas and the Wheatstone bridge can be nulled and the recorder, usually a 0-5 or 0-10-mv dc recording potentiometer, will read zero.

After the chromatograph has been balanced with carrier gas only, about 6 ml of sample gas is injected into the carrier gas at the column entrance and immediately the sample is adsorbed by the column packing material. Since the carrier gas forces the sample through the column packing, there is a time when the vapor pressure of the weakly-adsorbed CO_2 component exceeds its affinity for the packing and commences to pass preferentially through the column and emerge with the carrier gas as a binary mixture.

The detector senses the difference in thermal conductivity between the carrier gas only (reference cell) and the binary mixture of carrier gas and sample component (measuring cell). The corresponding bridge output is fed to the recorder, resulting in a plot shown in Figure 2. Here, carbon dioxide is eluted first, followed in succession by methane, ethane, and finally ethylene.

Since each component is separated timewise from the other in the elution sequence the record produced is a series of peaked curves, one for each component. The time between the sample injection and the moment when the CO_2 peak is a maximum is termed the retention time for the CO_2.

COLUMNS

The chromatographic column is usually made of ¼-in.-OD metal tubing varying in length from a few inches to over 40 ft. The desired straight length is filled with solid adsorbent (adsorption chromatography) or liquid-coated material (partition chromatography) and then shaped to fit into the chromatographic instrument. Short columns are bent into U-shapes, while long columns are shaped into helices by winding on an arbor.

Gas-adsorption columns

Experience indicates that activated forms of alumina, carbon or charcoal, and silica gel are suitable packing materials for adsorption columns. They efficiently separate low-molecular-weight gases, including the C_3 range of hydrocarbons. They are not suitable for separating higher-molecular-weight mixtures because of the larger forces with which the components are bound to the adsorbent.

As a guide to the selection of adsorbents:

▶ activated alumina will adequately separate (at 50 deg C) CO_2, CH_4, C_2H_6, C_2H_4, C_3H_8, and C_3H_6 with a total sample elution time less than 15 min

▶ activated silica gel (at 50 deg C) separates the same gases in a similar manner, but with longer retention times and a different order of separation: CH_4, C_2H_6, CO_2, C_2H_4, C_3H_8, and C_3H_6. Therefore, the total sample elution time will be longer than for an alumina column

▶ activated carbon or charcoal provides good separation for H_2, CO, CH_4, CO_2, C_2H_2, C_2H_4, C_2H_6, C_3H_8, and C_3H_6. At 50 deg C the column separates H_2, CO, and CH_4 into sharp symmetrical peaks. The balance of the listed components will "tail out" and be asymmetrical. For CO_2 and the C_2 and C_3 gases to be separated without tailing out, the

column temperature must be more than 100 deg C.

The elution time in adsorption columns for the C_4 and heavier hydrocarbons becomes excessively long, and results in poor resolution of the peaks. To separate these higher-moleculer weight gases and vapors, gas-liquid partition columns are used.

Gas-partition columns

Manufacturers of laboratory-model chromatographs offer a great deal of factual information about gas-partition column packings, coating materials, and retention times, and about a large number of gases and vapor components. This information, however, does not necessarily apply to plant-stream chromatographs, the subject of discussion here. With these analyzers it is expected that:

- each analysis will not take longer than 20 min
- the analyses will be repeated continually for months at a time
- the separation efficiency of the column will not decrease with usage under normal conditions

Thus, column requirements for a plant-stream analyzer are considerably different and much more stringent than they are for laboratory chromatographs making the same analysis. For example, Celite 545 coated with dimethyl formamide provides excellent separation of C_4's in a laboratory analyzer, but this packing is not at all usable in a plant-stream analyzer because its high vapor pressure continually depletes the liquid coating—which is equivalent to shortening the column so that the peaks commence to run together as the packing becomes depleted. Also, the vaporized liquid-coating in the column coats the detectors in the measuring cell—this creates zero drift, noise in the output signal, and eventually renders the measuring cell useless.

Even under the best conditions there is a definite limit of useful life for partition columns. However, by careful selection of coating materials and by resetting zero at the end of each analysis, column lives as long as 10 to 12 months have been attained.

Practical liquid-partition columns for plant stream chromatographs should be based on the following:

1. Liquid coatings must be chemically inert.
2. The liquid coating should have low viscosity to assure (a) ready coating of the packing particles; (b) solubility of the sample components as they move over the coating; and (c) elution of the components by the carrier gas.
3. The boiling point of the liquid coating should be at least above 200 deg C; this makes the vapor pressure of the coating small enough to prevent it, for a period of many months, from vaporizing into the mobile phase of the column.
4. The molecular structure of the liquid (stationary) phase should be one that acts as a good solvent for the sample components, and its internal forces (polar moments) should facilitate the separation of the sample components.
5. Column length should be long enough to provide the necessary degree of separation or resolution and short enough to provide large output signals. Because of these criteria, the procedure for obtaining optimum values for both peak signal height and good resolution becomes one of "cut and try".

Detectors

Column output consists either of the carrier gas alone or a binary mixture of carrier gas and an eluted sample component. A detector, located close to the end of the column, senses the difference in a property of the output. Some properties thus used are thermal conductivity, heat of adsorption, infrared adsorption, dielectric constant, and photometric titration. Thermal conductivity measurement gives the best overall results for plant-type chromatographic analyzers in terms of cost, sensitivity, stability, signal amplitude, and response to signal changes.

The thermal conductivity properties of a carrier gas and those of each effluent binary mixture are measured by temperature-sensitive elements immersed in the gases of interest and connected into a standard Wheatstone bridge. Two popular types of thermal conductivity detectors are presently used in the quantitative measurement of sample components. But before discussing them, some of the factors concerning an effluent binary mixture that effect the design of a detector should be considered.

Assume a controlled flow of 60 cc/min of carrier gas through a column and an injected 6-cc sample volume containing 2-percent ethane. Assume further that the elution time of ethane is ½ min. The total amount of ethane to be eluted is thus 0.12 cc admixed with 30 cc of carrier gas in varying degrees of concentration. At an appropriate time the ethane vapor pressure exceeds the force of its affinity for the column packing, desorbs, and starts to elute from the column. In the succeeding ½ min the ethane concentration in the effluent mixture will go from zero to a maximum and back to zero again.

The smallness of this concentration of ethane indicates that it is important to obtain a maximum signal throughout the recording of a peak which represents the small component concentration for values approaching zero at each end of the peak. Any dilution of the true effluent mixture with additional carrier gas leads to doubtful readings. Although it is difficult to completely avoid, dilution can be minimized by keeping the detector's internal volume small and by connecting the detector to the immediate effluent end of the column.

Convection currents set up by the flow of gas past the detector element introduce errors in thermal conductivity readings. The National Bureau of Standards suggests a 20 cc/min maximum flow.

Thermal conductivity detector cells use either resistance wire or thermistors. In the resistance-wire type, the electrically-heated filament is either a straight length of wire or ribbon, or a wire helix. The filaments are mounted in a cylindrical cell and

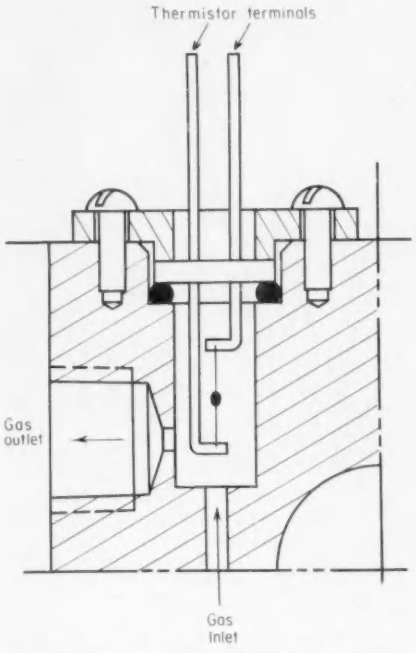


FIG. 3. One of two thermistor thermal conductivity cells used to detect binary gas mixture coming out of the column.

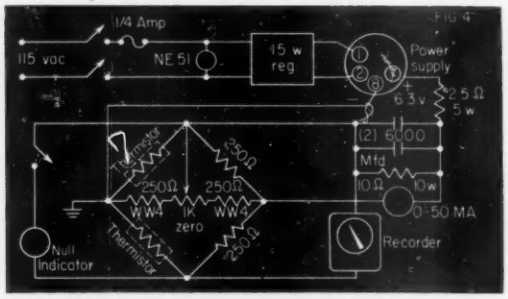


FIG. 4. Typical Wheatstone bridge used with two thermistor thermal conductivity cells to produce chromatogram on recorder.

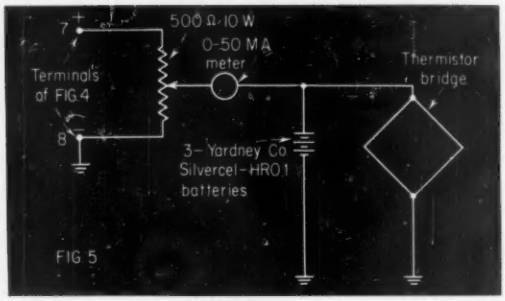


FIG. 5. Alternate power supply for circuit of Fig. 4 uses small battery to smooth out voltage fluctuations in power supply.

the binary mixture flows over the heated-wire surface. The heat lost by thermal conductivity depends on the gas mixture flowing past the filament. Thus, the wire, sensible to this heat loss, changes its resistance proportionately. A second (reference) cell carries a fixed flow of carrier gas. The two cells are associated in a Wheatstone bridge which develops an unbalance signal proportional to the difference in thermal conductivity between the gases in the two cells. Care must be taken that the temperatures of heated detectors are not so high that they cause reaction between components of the sample or cause cracking of hydrocarbons.

A thermistor is a resistance element with a large negative temperature coefficient. A typical thermistor used in chromatographic apparatus has a resistance approximating 1,200 ohms at 20 deg C and reduces to 250 ohms at 50 deg. C. Because they have highly nonlinear characteristics, two thermistors used in a detector must be a matched pair. Figure 3 shows a single thermistor cell for thermal conductivity measurements in chromatography. Here the thermistor is a bead about 0.010 in. in diam.

Figure 4 shows two thermistors cells connected in a Wheatstone bridge. An essentially similar circuit can be used for resistance-wire cells, but then consideration must be given to circuit values of bridge resistances and to the polarity of the unbalance signal to compensate for the smaller-resistance, positive-temperature coefficient resistance wire cells. Figure 5 shows an alternate power supply for the bridge in Figure 4. The small battery acts as a surge tank for objectionable voltage fluctuations and smooths them out much better than the capacitor bank in Figure 4.

Carrier gases

The most common carrier gases used with thermal conductivity detectors in vapor-phase chromatography are helium, hydrogen, nitrogen, and air. Selection of any one is based on the best compromise between sensitivity, availability, cost, and safety. For instance, hydrogen provides high sensitivity, is readily available, but can explode. Clean, dry air and nitrogen are readily available at low cost, but are not as sensitive as helium. Helium is available in the U. S. at moderate cost, and provides high sensitivity—in most cases greater than hydrogen. Outside the U. S. helium becomes difficult to obtain since the government restricts its export.

Sample handling

Filters for removing water, oil, and dirt from the sample and carrier gases must be inserted in the piping from the sample-takeoff point to the entrance to the column. Such filters usually come with the chromatograph but specific plant process and conditions may require more than are provided.

The effect of contaminants that enter the column, either with the carrier gas or with the gas sample from the process stream, drastically reduces the ability of a column to separate the sample components, and quickly renders it useless. The reason for this is that as the contaminants deposit on the packing material the effective area of separation decreases

and the retention times shift from their initial calibrations. The shift in calibration is particularly detrimental when plant chromatographs operate continually with a programmed time schedule, as is required for automatic analysis and control of plant streams. The operation of a programmed plant analyzer, including additional information on sampling, will be discussed in a following section.

ANALYZING THE RECORD

The percent-by-volume concentration of each component can be determined by planimetering to find the area enclosed by each recorded peak, correcting each area to compensate for the thermal properties of the binary mixture containing the sample component represented by that area, and then dividing each corrected area by the sum of all corrected areas. The correction factor for each peak can be determined by eluting a calibrated sample mixture of known gases and concentrations through the column. However, this method of finding concentration is a laborious task.

An alternative is to calibrate with a standard mixture and relate peak height of each component curve to its corresponding gas concentration in the known mixture. To apply this method in plant-type chromatographs:

- the volume of the injected sample must be the same for all repetitive analyses
- the flow of carrier gas must be maintained constant within plus or minus 0.1 percent
- the carrier gas, the injected sample, the column, and the detector must be maintained at a constant temperature (for instance, at 50 deg C plus or minus 0.25 deg C).
- the column length, diameter, and packing material must be such that each component is distinctly separated and symmetrical

In the analysis of vaporized liquids the peaks are often broad and asymmetrical so that area measurement becomes the only criterion for accurate quantitative determinations. Some manufacturers of plant-type chromatographs are attempting to provide automatic integration of the area under the curves and thus a recorded area value for each component. This feature is expected to become commercially available this year.

Resolution

A well-resolved peak found on a chromatographic record is one which is narrow at the base compared with its height and is symmetrical. Perkin-Elmer's H. H. Hausdorff suggests a resolution figure of merit defined as the ratio of the retention time to the width of the peak measured at half its peak height. The retention time and the half-width are both measured in the same units of time. Hausdorff recommends a ratio of 15 or greater for good resolution.

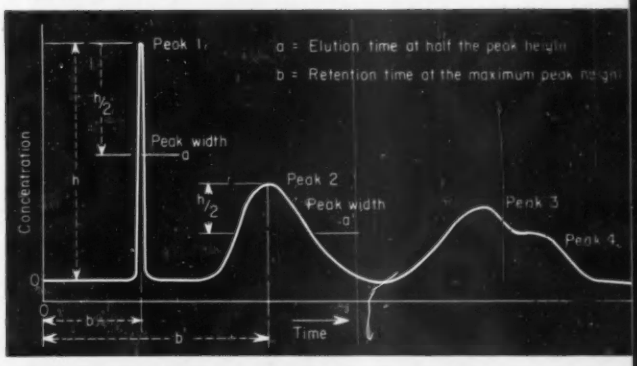
Figure 6 shows peaks having good and poor resolution. The figure of merit of b/a for peak 1 is 20, while that of b'/a' for peak 2 approximates 3. The poor resolution of peak 2 and its departure from symmetry, tailing out as the elution time increases, indicate the effect of dilution or diffusion within the column during the long retention interval and make accurate quantitative evaluation in terms of peak height impractical.

The resolution figure of merit is thus useful in judging the effectiveness of column materials in producing peaks suitable for peak height measurement of concentrations. In Figure 6 the packing material could not separate peaks 3 and 4 and they elute as a combined peak. The concentrations described individually by peaks 3 and 4 are indeterminate to any reasonable degree of accuracy.

PLANT-STREAM ANALYZER

In using vapor-phase chromatographic analyzers, industry personnel demand that the recorded analytical data be at least as accurate as those obtained from samples analyzed by control laboratories. They want the frequency of repetitive analyses to be compatible with the time lags of the processes so as to allow a timely adjustment of process variables to deviations from desired values. Furthermore, they want to be able to read, say, a 4-percent concentra-

FIG. 6. In peak 1, the ratio b/a is about 20 and indicates good resolution. Peak 2 has a b'/a' ratio of about 3 and indicates poor resolution.



Component	Actual Range of Variation	Assigned Analyzer Range	Widest Acceptable Limits for Reproducibility
A	2-4 percent	0-5 percent	±0.1 percent
B	4-8 "	0-10 "	±0.2 "
C	12-18 "	0-20 "	±0.4 "
D	1-3 "	0-5 "	±0.1 "
E	5-9 "	0-10 "	±0.2 "
F	6-14 "	0-20 "	±0.4 "
G	25-60 "	0-100 "	±2.0 "
H	40-90 "	0-100 "	±2.0 "

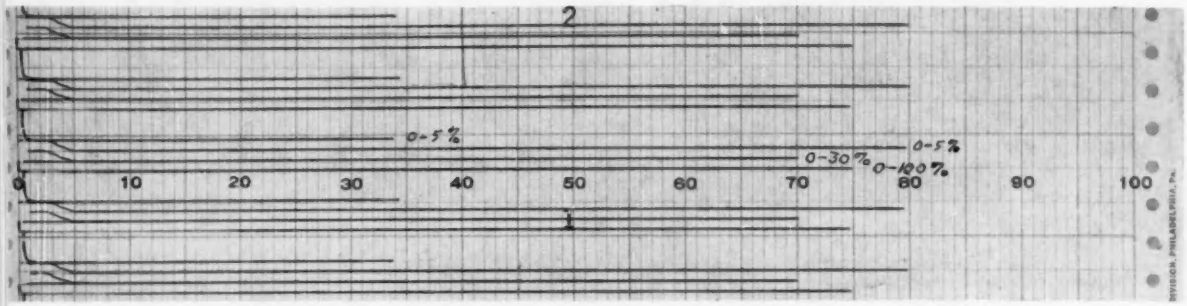


FIG. 7. This bar graph of the output of a chromatographic column indicates concentrations of each component by the amplitude of its corresponding bar.

tion of one sample component and an 80-percent concentration of another component with equal accuracy and facility. Other requirements: good reproducibility of measurement for the same sample composition for very long periods of time, very little maintenance, and easy accessibility of all parts.

To illustrate how a plant-type chromatographic analyzer operates, assume an eight-component sample having concentrations falling within the percent-by-volume ranges listed in the table. Assume further that the instrument must analyze each component to a reproducibility of at least plus or minus 2 percent of the assigned analyzer range within which it falls.

For a recording potentiometer having a 0-5 millivolt range, the output signal from the thermistor bridge must be about 10 to 15 mv for the minimum component range concentration (in this case, 0-5 percent). This is necessary to provide for sufficient electrical signal attenuation so that the normal overall noise level of the system—which includes, among other things, small variations in carrier gas flow—will not visibly affect the recorded peak trace or bar graph. This scheme still makes the full sensitivity of the recorder available.

To cover the variability in concentration experienced by the eight components, four analyzer ranges are assigned (suppressed ranges cannot presently be made available because of the complex electric circuitry involved) and eight variable signal attenuators are included in the thermistor bridge circuitry (equal volumes of different gases produce vastly different output signals from the measuring cell, Figure 2). Each attenuator will be automatically connected in when the time arrives for the particular component peak to be recorded. A multicam timer system controls a series of switches according to cam settings that correspond to the effluent time for each binary mixture entering the measuring cell. In this manner, the full scale of the recorder is made available for each range of component concentration, and the reproducibility of a measurement can be recorded to better than plus or minus 2 percent of full scale.

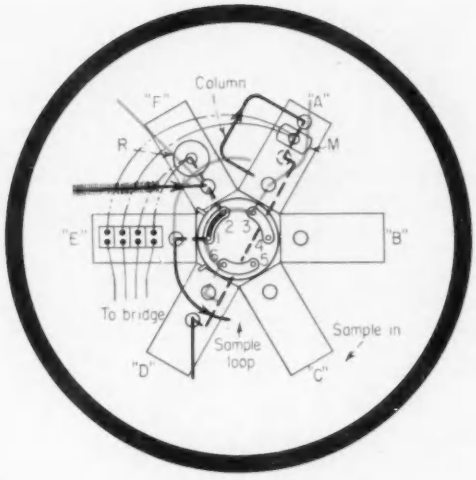
The peak-height method is applied in the continuously-programmed plant-stream analyzer and has led to the adoption of the bar-graph recording method, Figure 7. Here the strip chart is stopped for a period of time required to record a peak so that only a line—the peak height—is recorded. The chart advances between peak recordings ($\frac{1}{8}$ in. approximately) and usually a double space ($\frac{1}{4}$ in. or so) is allowed between the recording of the last peak of one sample and the first peak of the following sample. The starting and stopping of the chart-drive motor is commanded by a recorder-actuator switch and time delay relay combination.

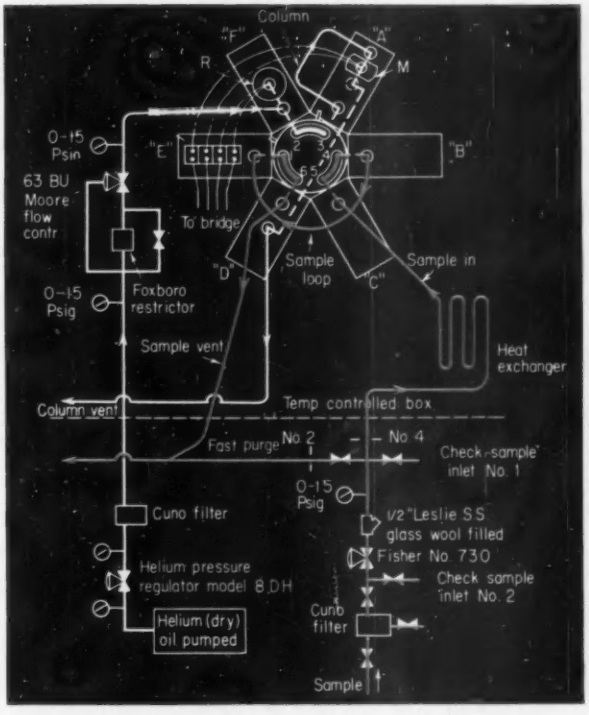
To maintain the accuracy of the analyses over long periods within the limits of reproducibility, and at the accepted calibrated values, it is necessary to hold a constant flow of carrier gas, a constant volume of injected sample, and constant temperature for the analytical system. In addition, any tendency of the bridge to exhibit appreciable zero drift must be obviated. To guard against drift, the recorder is automatically adjusted to zero at the end of each complete sample analysis, when only carrier gas is present in both cells.

To analyze a succession of gas samples according to an automatic timed program, a means must be provided to:

(1) trap a fixed volume of sample;
(2) connect it to the column;
(3) admit the carrier gas to the trapped volume of sample and force it into the column;
(4) allow the carrier gas to flow until all of the last binary mixture has passed through the measuring cell;
(5) connect the fixed-volume sample loop to the sample stream, while (4) is proceeding, to keep it full of new sample;
(6) following (4), let the carrier gas continue to flow through the column until the recorder reads zero again;
(7) momentarily stop the flow of sample into and out of the sample loop so that a fixed volume of fresh sample is trapped therein.

A two-way, multi-port valve (rotary or linear), actuated by a solenoid lever or valve commanded by the multicam-timer system, carries out the above schedule. A typical rotary valve machined from hexagonal bar stock is shown in Figure 8, with





FIGS. 8 and 9. The sampling system and valve assure that exactly the same sample volume is obtained for every analysis cycle and validates using peak-height measurement for determining concentrations.

the actuating means omitted for the sake of clarity. The sides are turned upward to show the various connections, gas paths, and locations for the reference and measuring cells. In the center are six ports covered by a circular Teflon cap into which three curved slots about 1/32 in. deep have been cut. Each of these slots provides a gas-flow path between two ports. The ports are numbered clockwise 1 through 6. All of the dotted lines are drilled connections inside the valve body. The small circles in the sides of the valve body are tubing connections.

The solid heavy line represents the flow of carrier gas (helium) and the colored line represents the flow of sample. The figure shows the sample flowing through the sample heat exchanger (to maintain constant temperature), through valve ports 5 and 4, through the sample loop, back through ports 1 and 6, and then into the sample vent lines. The fresh sample flushes out the sample loop, the carrier flushes out the column, and (5) and (6) are satisfied.

Figure 9 shows a portion of the sampling unit of Figure 8, but here the Teflon cap has been rotated so that now ports 1 and 2, 3 and 4, and 5 and 6 are connected in pairs. The rotation time is less than 1 sec; this means that only a momentary change occurs in the helium flow through the column and measuring cell. The important thing is that no sample flows into or out of the sample loop when the slot in the cap is moving from port 1 toward port 6, and when it is simultaneously moving from port 5 toward port 4. In this way the sample loop becomes filled with a trapped volume of fresh sample for the succeeding analysis.

Realization of requirement (3) is starting: as helium pushes the fresh sample through the sample loop into the column, the components are held to the column packing according to their affinities for it, and the helium continues to flow through and out through the measuring cell. Subsequently, the vapor pressure of each component overcomes its affinitive force and the binary mixtures start to elute and pass through the measuring cell.

At this time the cap returns to the position of Figure 8 in which the helium continues to elute the sample components, and the sample loop, being connected again to the sample stream, is purged of helium and flushed out with a fresh sample. Shortly after the last binary mixture has passed out of the measuring cell [completion of requirement (4)], the bridge balance and recorder zero are automatically reestablished. The cycle of events then repeats.

CHROMATOGRAPHY DEFINITIONS

Adsorption: The adhesion, in an extremely thin layer, of the molecules of gases, of dissolved substances, or of liquid to the surfaces of solid bodies with which they are in contact.

Elution: The separation or purification of materials by washing with carrier gas.

Partition coefficient: The solubility of each component in the sample in the liquid coating on the inert column packing (the stationary phase).

Henry's law: The mass of gas dissolved by a given volume of solvent at constant temperature is proportional to the pressure of the gas with which it is in equilibrium. Another way to say this: The solubility of a gas is proportional to its partial pressure.

REFERENCE

VAPOR REFRACTOMETRY (GAS CHROMATOGRAPHY), H. H. Hausdorff, The Perkin-Elmer Corp., Norwalk, Conn.

Force-Reflecting Servos Add "Feel" to Remote Controls

Servomechanisms, commonly regarded only as position and velocity transmitters, can now boast of a new dimension—force. Force-reflecting servos incorporated in remote manipulators give the operator many of the real sensations he would experience if he were controlling operations right at the slave station. Designing these systems calls for special care because of the need for stability over wide load ranges. To obtain this stability, the four-terminal network analogy is used in preference to Nyquist and root-locus techniques.

J. R. BURNETT, The Ramo-Wooldridge Corp.

By definition as well as design, the conventional servomechanism is primarily a position transmitter: the output is said to "reflect" the position of the input. Certain types, especially the fast-response group, whose output speed is proportional to input speed, can also transmit velocity information, and this group is broad enough to satisfy most needs. However, a new area of servo usage has developed in which not only position and velocity, but also the force between two mechanically isolated points, must be transmitted. The servo system for this application must be bilateral, in contrast to the more common unilateral control (Figure 1), permitting the transmission of force and position from the operator to the load or slave and, simultaneously, from the load back to the operator or master (Figure 2). A servomechanism with these capabilities is said to be force-reflecting.

Incorporating several force-reflecting systems into a manipulator or "mechanical hand" yields a device which is an ideal extension of the operator's arms and fingers. Such a manipulator brings obvious benefits to processes and experiments involving hazards to the operator. Force-reflecting servomechanisms plus three-dimensional television enable an operator to be a safe distance away from the process. (With radio links between master and slave stations of the force-reflecting servo, this distance can be thousands of miles.) This means, for example, that a pilot can remain on the ground, yet receive many of the sensations he would normally feel in the air.

One of the important benefits of force-reflecting servos is less need for operator training. This is because the system sends to the operator's arms and fingers most of the normal sensations that he would have were he doing the experiment locally. The possibility of exerting too much force, a common problem in other types of manipulators, is not present here.

Force-reflecting servomechanisms may be thought of as two unilateral servomechanisms connected back to back, with the output of one being geared to the input of the other. When properly designed, such a system transmits positions and forces bilaterally from the master and slave sides. Thus the electrical equivalent of a force-reflecting servomechanism is simply an ideal transformer.

A convenient way to analyze force-reflecting servomechanisms is by means of analogies between electrical and mechanical circuits. In the common mass-capacitance analogy, force in the mechanical system corresponds to current in the electrical system, and velocity corresponds to voltage. With this natural analogy, so called because the topologies of

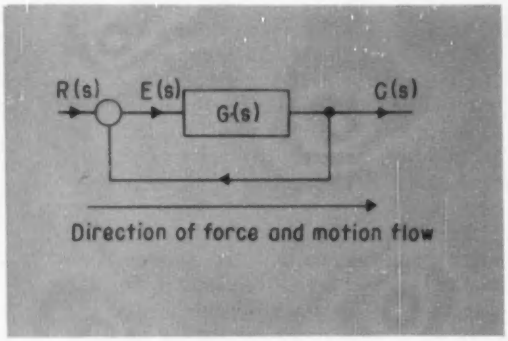


FIG. 1. Block diagram of simple unilateral servomechanism.

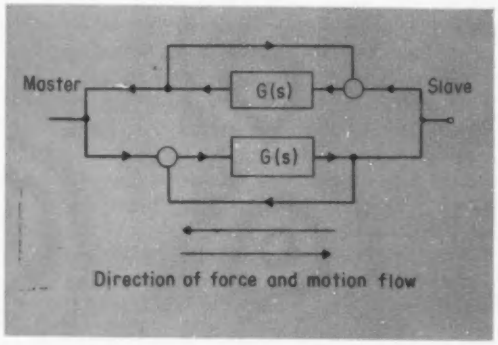


FIG. 2. Block diagram of bilateral or "force-reflecting" servomechanism.

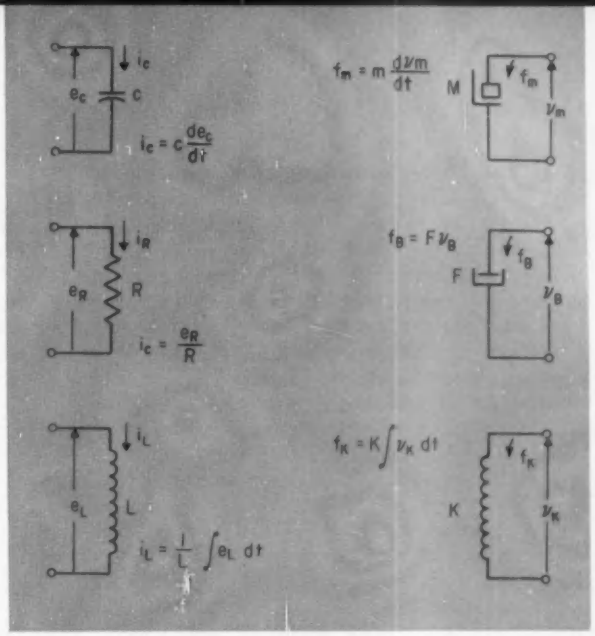


FIG. 3. Electrical-mechanical analogies employed in representing servomechanism as a four-terminal network. Mass, damper and spring are simulated by capacitance, resistance and inductance.

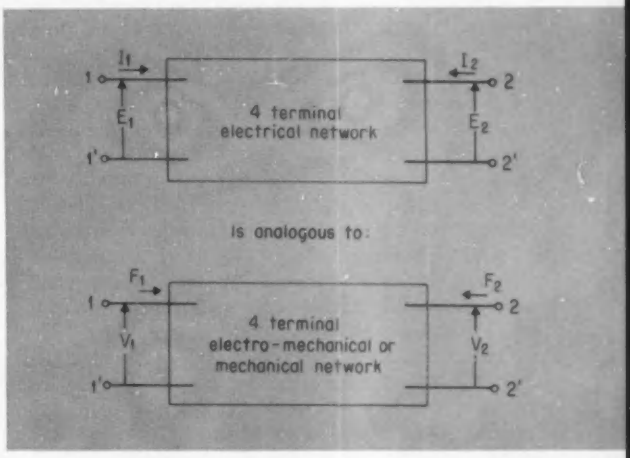


FIG. 4. In networks shown, current and voltage are analogous to force and velocity.

the mechanical and electrical networks are identical, the analysis of a force-reflecting servomechanism can be restated as the analysis of four-terminal electrical networks having two currents and two input voltages. The problem is simply to design the contents of the four-terminal box subject to physical constraints on equipment.

Ideally, whatever impedance is connected across the 2-2′ terminals of the electrical network would be seen at the 1-1′ terminals of the electrical network. In the case of the force-reflecting servo, the impedance-measuring device at the 1-1′ terminals is, of course, the operator. The impedance connected to the 2-2′ terminals is whatever the operator happens to be manipulating.

A four-terminal network is a characterization of one degree of freedom of the force-reflecting servomechanism. A complete manipulator requires approximately seven degrees of freedom per arm so there are at least 14 force-reflecting servomechanisms in a manipulator for two-hand use.

Force stability problem

Unilateral servomechanisms are usually designed for a single load or a known limit of load variation. Indeed, load variations on a single servomechanism may very well affect its performance and, under certain conditions, make it unstable. In a force-reflecting servomechanism composed of two unilateral servos connected back to back, the stability problem is even more acute: the nature of the load is manipulator applications, which cannot very well be deter-

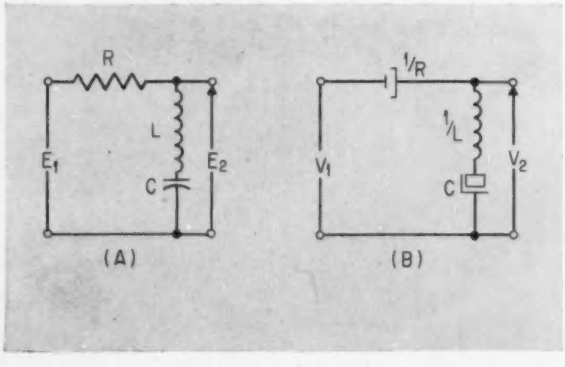
mined in advance, and which might vary anywhere from a near-zero mass, spring and damper combination to that of an infinite mass, spring and damper combination. The latter would occur if, for instance, the slave arm hit a wall and the operator attempted to keep it moving against the wall. Moreover, the loads involved do not tend to be perfectly linear. The forces and velocities in the turning of a lead screw, for example, are apt to encounter a considerable amount of nonlinear friction. A basic objective in the design of force-reflective servomechanisms then, is stability under any load conditions.

The classic tool for determining whether a closed-loop system is stable is the Nyquist diagram. Recently, the root-locus method has been employed. However, in the application being considered, the use of the Nyquist diagram or the root-locus technique would involve a new plot for each of the particular load conditions. An exorbitant amount of work could be done without really determining how the servomechanisms should be designed to assure stability under all load conditions.

The method to be discussed here is based upon four-terminal electrical network theory. It is a known fact in electrical network theory that a passive four-terminal electrical network will be stable regardless of the passive load connected to the output of this network. The procedure, then, for stabilizing the force-reflecting servomechanism is to make it analogous to a passive electrical network in such a way that its terminal conditions exhibit the stability characteristics known to be obtainable in the actual network. Though perhaps a different servo stability criterion than has been used in the past, this becomes a very powerful technique when the load conditions of the closed-loop system vary considerably.

Two conditions must be met if a four-terminal network is to remain stable whenever a passive load is connected to its terminals. The first is that the driving point impedances of the network must be positive real. Positive reality makes certain that the impedance functions along the $j\omega$ axis and in the right half of the s plane have a positive real or resistive component. The two admittances which must be tested for positive reality are Y_{11} and Y_{22}.

FIG. 5. Analogous electrical (A) and mechanical (B) networks.



The second is satisfaction of the residue condition In a very broad sense, the residue condition simply assures that the loop gain of the network does not exceed unity when the phase angle is near 180 deg. The residue condition also implies that there are certain relationships between the poles of the admittance parameters. Definitions of these parameters are given below.

One of the problems in this approach is obtaining the admittance parameters for the various components in the loop. It is relatively easy to find the transfer functions of most servo components, but obtaining the admittance parameters of a servomotor requires special studies.

Specification problem

The specification problem is eased considerably if electromechanical analogies are considered in forming the requirements for a force-reflecting servomechanism. The relationships between electrical and mechanical quantities of this analogy are illustrated in Figure 3. Because, as has been said, the topologies are identical, forces flowing into the force-reflecting servomechanism are analogous to currents flowing into the four-terminal networks. In addition, the velocities at both the input and the output of the force-reflecting servomechanism are analogous to the input and output voltages of the four-terminal network. This is illustrated in Figure 4.

By means of the analogies, admittance parameters of the four-terminal mechanical network may be defined exactly as they would be for a four-terminal network. With respect to Figure 4, the admittance parameters are defined as follows (for both the mechanical and the electrical networks):

$$Y_{11} = \frac{I_1}{E_1} \text{ when } E_2 = 0$$

$$= \frac{F_1}{V_1} \text{ when } V_2 = 0$$

$$Y_{12} = \frac{I_2}{E_1} \text{ when } E_2 = 0$$

$$= \frac{F_2}{V_1} \text{ when } V_2 = 0$$

$$Y_{22} = \frac{I_2}{E_2} \text{ when } E_1 = 0$$

$$= \frac{F_2}{V_2} \text{ when } V_1 = 0$$

$$Y_{21} = \frac{I_1}{E_2} \text{ when } E_1 = 0$$

$$= \frac{F_1}{V_2} \text{ when } V_1 = 0$$

There are definite relationships between transfer functions and these admittance parameters. They are expressed by the following equations:

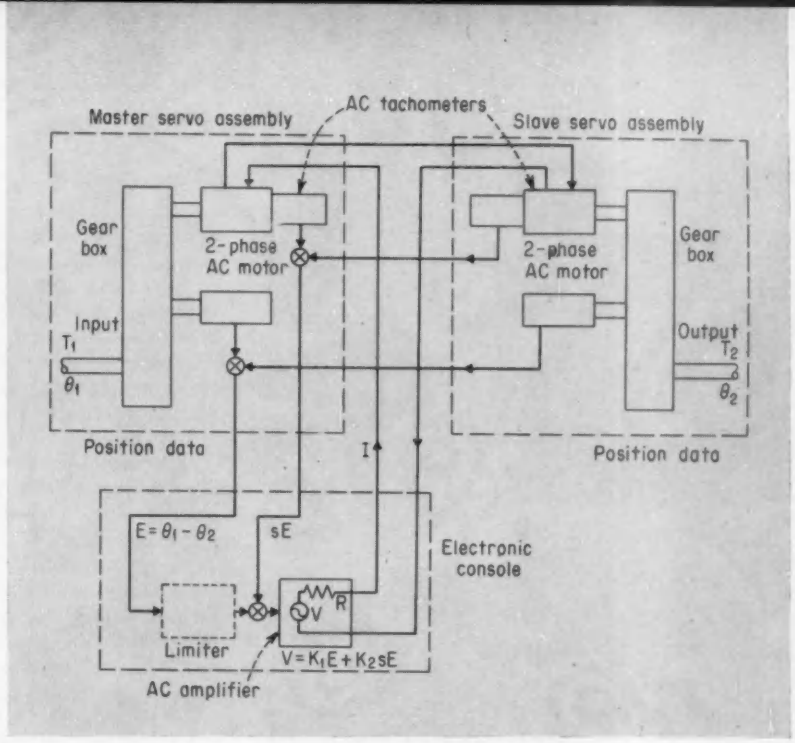


FIG. 6. Symbolic diagram of force-reflecting servo used in Model 2 manipulator designed by Argonne National Laboratory.

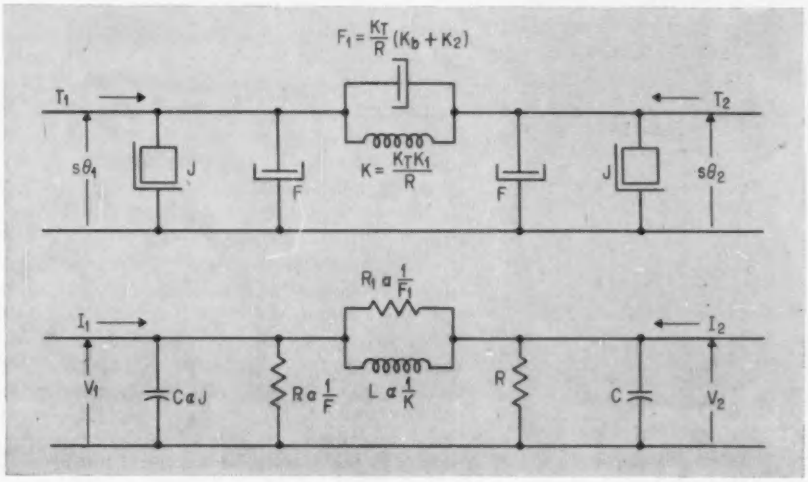


FIG. 7. Mechanical and electrical networks representing 1 deg of freedom of the Model 2 manipulator.

$$\frac{E_2}{E_1} = \text{transfer function} = \frac{Y_{12}}{Y_{22}}$$

$$\text{and } \frac{E_1}{E_2} = \frac{Y_{21}}{Y_{11}}$$

Each of the admittance parameters is a rational algebraic function because it is the ratio of two polynomials in the complex frequency variables. Since the electromechanical networks are equivalent here to passive four-terminal electrical networks, certain known relationships exist between the poles and zeros of these admittance parameters.

The use of admittance parameters for solving electrical or mechanical network problems is considerably more general than is the use of transfer functions alone. Of course, it may be argued that admittance parameters are simply a form of a transfer function and this is perfectly true. But admittance parameters enable one to take into the account the loading effects which may occur at the output terminals of transfer functions. This may not be done readily with conventional transfer functions alone.

The admittance parameters and the analogy mentioned above expedite the transition from electrical to mechanical networks, as shown by the above equations. The analogy also facilitates the transition of an actual electromechanical network to either an all-mechanical or all-electrical network. Suitable scale factors may be incorporated into the analogy to make

convenient simulations or computations of the various variables.

Analysis examples

The first-order analysis of the Argonne National Laboratory Model 2 servo represents an application of these ideas to force-reflecting servomechanisms. A diagram of the system is shown in Figure 6. Here the idea of back-to-back servos is not employed. The contents of the blocks are somewhat idealized but they serve to illustrate the point of the approach to the problem very well. In this particular example, it is easy to write down the dynamic equations of the system in Laplace transform form and these are

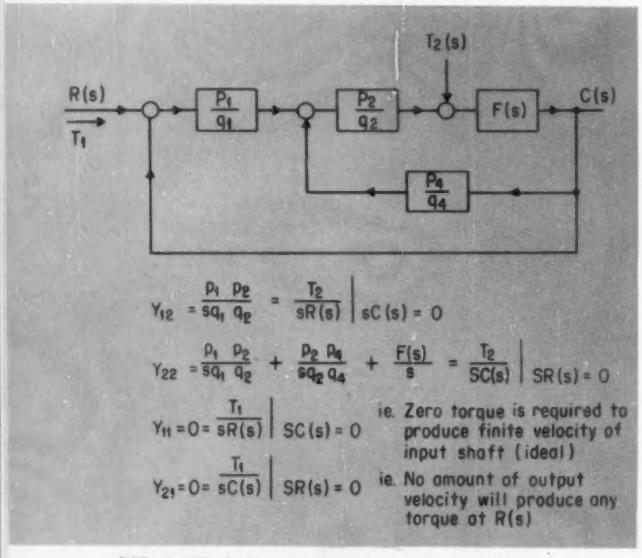

T2(s)
R(s)
T1
P1/q1
P2/q2
F(s)
C(s)
P4/q4
Y12 = P1 P2 / sq1 q2 = T2 / sR(s) | sC(s) = 0
Y22 = P1 P2 / sq1 q2 + P2 P4 / sq2 q4 + F(s)/s = T2 / SC(s) | SR(s) = 0
Y11 = 0 = T1 / sR(s) | SC(s) = 0 ie. Zero torque is required to produce finite velocity of input shaft (ideal)
Y21 = 0 = T1 / sC(s) | SR(s) = 0 ie. No amount of output velocity will produce any torque at R(s)

FIG. 8. Block diagram of unilateral servomechanism and definition of its admittance parameters.

given below. Note that rotational quantities could as well be used as the mechanical analogy.

$$T_1 - K_T I = (Js + F)\, s\, \theta_1 \quad (1)$$

$$T_2 + K_T I = (Js + F)\, s\, \theta_2 \quad (2)$$

$$V = K_1 (\theta_1 - \theta_2) + K_2\, s\, (\theta_1 - \theta_2) \quad (3)$$

$$IR = V + K_b\, s\theta_1 - K_b\, s\theta_2 \quad (4)$$

Equations 1 and 2 are torque equations, where J is the motor and gear train inertia; F the mechanical viscous friction; s the Laplace transform variable; and K_T the torque constant. T_1 and T_2 are externally-applied torques, while K_b is the back-emf constant. All values are referred to the input and output shafts of the servos. The equations assume a completely symmetrical and linear system. They can be written directly by reference to Figure 6. Their manipulation yields the admittance parameters of the system. These admittance parameters are summarized in the following equations.

$$Y_{11} = Y_{22} = J\, s + F + \frac{K_T}{R}\left(K_b + K_2 + \frac{K_1}{S}\right) \quad (5)$$

$$Y_{12} = Y_{21} = -\frac{K_T}{R}\left(K_b + K_2 + \frac{K_1}{s}\right) \quad (6)$$

Having the admittance parameters, it is possible to write down an equivalent electrical or mechanical network which illustrates what one axis of the force-reflecting servomechanism is like. In a more complicated example, generalized network synthesis techniques might be employed to construct the topology of the network. In this case, it may be found by inspection. The electrical network configuration that is equivalent to the manipulator axis is given in Figure 7. Also shown is the mechanical network configuration equivalent to the manipulator. It should be pointed out that these electrical and mechanical networks are valid for only one of the axes of the manipulator. The actual manipulator, of course, contains at least seven degrees of freedom or seven sets of such equivalent circuits.

The stability of this system under any load condition is obvious, since it is totally equivalent to a four-terminal, passive electrical network, even if the actual manipulator is a complicated closed-loop system with internal power sources. It should be pointed out that this is a linear type of analysis. In practice, the manipulator would exhibit certain types of nonlinearities which may produce oscillations that cannot be predicted by linear analysis.

The equivalent circuit indicates that the manipulator operates somewhat like a springy rod with half its mass concentrated at each end. The two concentrated masses are connected by a massless spring. Each of the masses can be considered operating with respect to ground by means of a bearing which has a certain amount of viscous friction, F. It is obvious that good feel would be obtained in such a system with the spring constant very high and the mass and the friction forces very low. For a given manipulator problem, where the magnitude of the input and the output forces are shown, suitable choices could be made for the spring constant masses and the dampers to produce good feel.

Synthesis problems

Working this problem backwards is desirable. For instance, one might first decide on the type of mechanical equivalent network that would produce a manipulator of good performance. He would also consider certain physical constraints of the systems, such as the performance of the servo motors. Then, the network would be expressed in terms of hardware.

One synthesis approach to this problem can be outlined. First, consider the manipulator as two unilateral servos connected back to back, as is shown in Figure 2. Each unilateral servo is characterized by only two finite admittance parameters. These

are transfer admittance parameter Y_{12}, from the input to the output, and output admittance parameter Y_{22}, which relates the disturbance torque to the output velocity of the system. Connecting two such unilateral devices back to back produces one bilateral device whose admittance parameters are simply the sums of the admittance parameters of the individual boxes. Thus, the Y_{11} of the manipulator is the output admittance of the backward servo; the Y_{22} of the manipulator is the output admittance of the forward servo; the Y_{12}, or the transfer admittance, of the manipulator is the transfer admittance of the forward servo; and the Y_{21} of the manipulator is the transfer admittance of the backward servo. The problem is now reduced to that of producing *unilateral* servomechanisms, given a specified Y_{12} and Y_{22}.

The second step, accordingly, is to synthesize a unilateral servomechanism with a specified Y_{12} and Y_{22}. The geometric assumptions in this process are given in Figure 8. It is further assumed that $F(s)$ is the fixed part of the system consisting partly of power amplifiers and servomotors, and that the rest of the components in the block diagram are at the disposal of the designer. With this geometry assumed, it is possible to solve, in general terms, for the Y_{12} and the Y_{22} functions. Knowing the required admittance functions and, in general, what can be done with this specific type of geometry and specific type of assumed compensation networks, these networks can be given values that will produce the proper characteristics in the unilateral servo. Back-to-back connection of the two servos, each one arrived at by the same process, will then assure that the single axis of the manipulator will perform as specified.

The accompanying table illustrates the numerical requirements of the admittance parameters for such a servomechanism, and Figure 9 shows the completed block diagram of the synthesized servo. It should be pointed out that there are many different types of geometries which could be assumed for the individual servos; indeed, one need not assume individual servos which are connected back to back. The great flexibility in this process makes it easier for the designer to meet the needs of a specific problem.

REQUIREMENTS FOR UNILATERAL SERVO USED IN A MANIPULATOR

1. BANDWIDTH = 5 RADIAN/SEC
2. DAMPING FACTOR = 1
3. OVERSHOOT = LESS THAN 10%
4. VELOCITY CONSTANT = 3
5. TORQUE CONSTANT = 10 (i.e., stiffness of servo output)
6. $F(S) = \frac{12.5}{S(S+1)}$

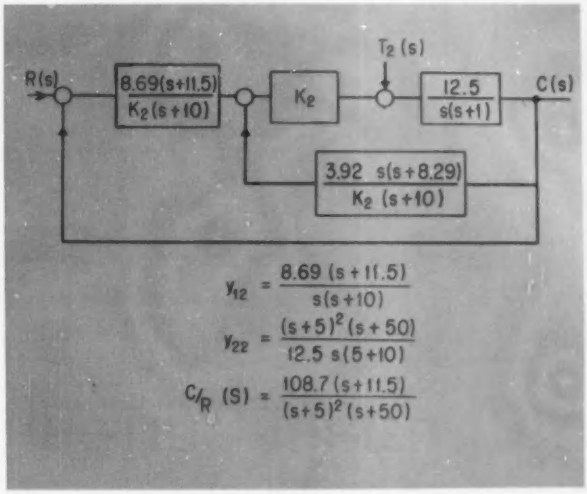


FIG. 9. Block diagram of synthesized unilateral servo.

In summary then, the design and analysis of force-reflecting servomechanisms is facilitated by, first, considering electromechanical analogies, and second, by casting the whole problem in terms of passive network theory. The big advantage of passive network analysis is that the servomechanism can be designed for stability without an excessive amount of labor. The process admits of analysis of systems, as well as the design or synthesis procedure outlined above.

ACKNOWLEDGEMENTS

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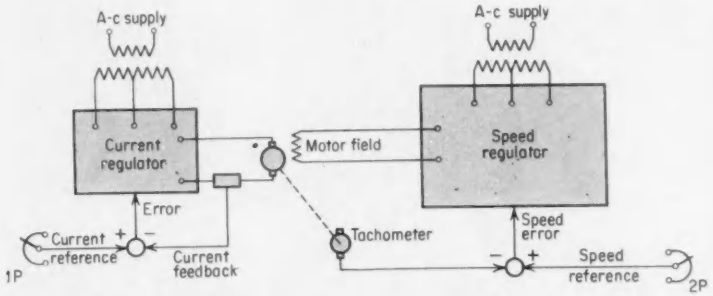


FIG. 1. Block diagram of basic constant-current system. Current regulator adjusts armature voltage as required to hold armature current constant.

Constant-Current Speed Control of DC Motors

New improvements continue to add impetus to the rising use of electronic adjustable speed drives. Latest refinements make possible for the first time regenerative braking and contactorless reversals. These features are available in a type of drive so unusual that it produces *reverse* torques from *forward* currents and increased speed by field *strengthening*.

E. H. DINGER
Specialty Control Dept., General Electric Co.

It is customary to think of the speed control of dc motors in terms of adjustable-voltage systems. In such drives, motor field voltage is either fixed or controlled over a limited range while the applied armature voltage is varied to provide speed changes. In regulated systems of this type, changes in load are accompanied by the automatic adjustment of armature voltage to maintain speed at the preset level.

There is another method for controlling the speed of a dc motor that is quite different and less well known. This method is known as the "constant-current" system. The original basic constant-current system had two great advantages over the adjustable-voltage drive, one being the ability to provide regenerative braking. This most efficient form of braking (where energy is not dissipated, but actually pumped back into the power lines) is not possible in standard electronic drives because of the "one-way" characteristic of rectifiers. The second advantage was motor reversals without heavy reversing contactors.

BASIC CONSTANT-CURRENT SYSTEM

The basic system, Figure 1, incorporates an armature current regulator and a speed regulator. The current regulator maintains a constant value of current in the armature of the motor regardless of motor speed or shaft load. It comprises an adjustable reference voltage for setting the desired current level; a current-measuring circuit for feedback; a comparison circuit to determine the error between desired and actual current levels; and amplifying and power circuits. The latter circuits respond to the error and produce an output of the proper amount and direction to cause the actual output level to correspond closely to the preset level.

The power circuit could contain a rotating amplifier, a dc generator, or a thyratron or ignitron rectifier. This article will cover only power circuits making use of thyratron or ignitron rectifiers. A suitable rectifier power circuit has a voltage rating enabling it to circulate at all times the desired current through the motor armature for any motor back emf up to rated. Its current rating will be the same as the armature current rating of the motor.

The current feedback signal can be obtained from a dropping resistor as shown in Figure 1. Generally, however, this signal is the rectified output of a current transformer whose primary windings are connected in the anode leads of the power tubes. The latter method provides a large voltage signal, isolation, and a minimum of power loss.

The basic components of the speed regulator include a dc speed reference voltage, adjusted manu-

ally by means of speed-control potentiometer 2P; a dc tachometer for supplying speed feedback; a dc amplifier and a power stage for supplying current to the motor field. The power stage is considered here to be a back-to-back thyratron rectifier for supplying any value of field current between rated positive and rated negative field current.

The speed regulator maintains speed simply by controlling torque. If the speed is not high enough, more torque is called for; if the speed is too high, torque is reduced.

Since the torque produced by a dc motor is proportional to the product of armature and field currents, the torque requirements of any shaft load within rating can be met by varying field current alone if armature current is held constant. Consequently, the field regulator error voltage operates through the amplifier and power stages to automatically vary motor field strength and thus provide the torque necessary for maintaining motor speed at the value called for by the control potentiometer.

Two important characteristics of the speed regulator are:

1. Field current is *increased* if shaft load *increases*.
2. Because of the reversing character of the field rectifier, any torque between rated positive and rated negative can be developed by the motor.

The first characteristic points up one of the major differences between the adjustable-voltage and constant-current systems: in the adjustable voltage system, net motor torque is *increased* if field current is *decreased*. The second characteristic highlights an additional difference between the two systems: in an adjustable-voltage drive whose armature circuit is supplied from a rectifier, reverse torque cannot be provided without some auxiliary "quick-slowdown" type of dynamic-braking circuit requiring an additional intermittently operated dynamic braking contactor. In contrast, the constant-current system supplies either positive or negative torque, so that the motor can be operated in either direction of rotation without reversing contactors. If the reference voltage is continuously adjustable between a positive and a negative value, the speed regulator will supply the correct field current and torque (when combined with the constant forward armature current) to operate the motor at any point from rated speed forward to rated speed reverse.

Fundamental relationships

The same fundamental relationships hold for a dc shunt motor regardless of the system in which it is used: 1) torque is proportional to the product of armature and field flux; 2) back emf is proportional to the product of speed and field flux; 3) applied armature voltage equals motor generated back emf plus IR drop; 4) power input equals the product of armature voltage and armature current; 5) mechanical power output equals the product of back emf and armature current.

Figure 2 shows the electrical relationships existing in the constant-current drive for certain conditions of operation. It will be noted that this drive is capable of operating in all of the four torque-speed quadrants described in Figure 3. It is a characteristic of this system that, regardless of the torque-speed quadrant in which the motor is operating, the armature current is always maintained in the positive direction.

Forward direction, motoring. In this quadrant, the motor is either driving a friction load or accelerating an inertia load in the forward direction. Therefore, the shaft or mechanical power may be said to

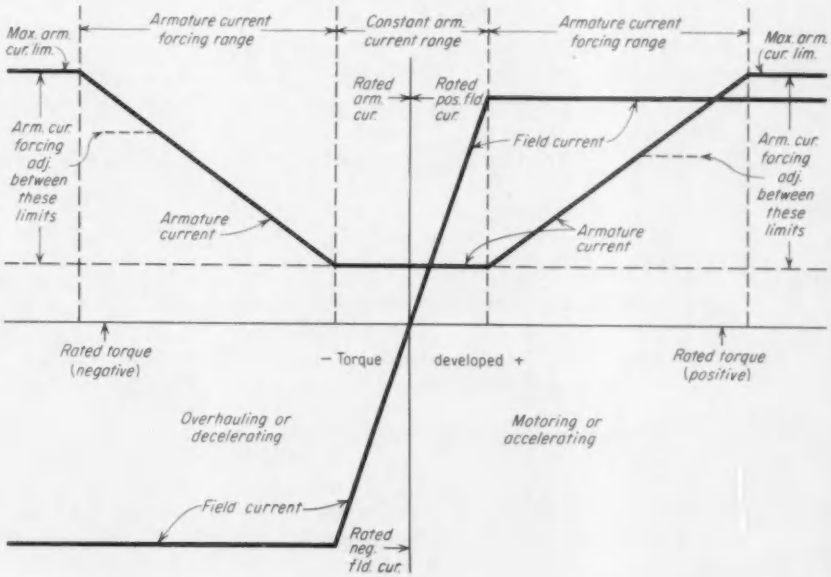


FIG. 2. Characteristics of modified constant-current system showing torque—armature current—field current relationships for any speed in the forward direction of rotation. Motor has armature range only.

be positive. Such operation requires a positive torque, hence positive field current. This positive field current and positive rotation generate a positive back emf. To circulate the needed value of armature current, the regulator acts to supply a positive terminal voltage that is greater than the back emf by the amount of the IR drop.

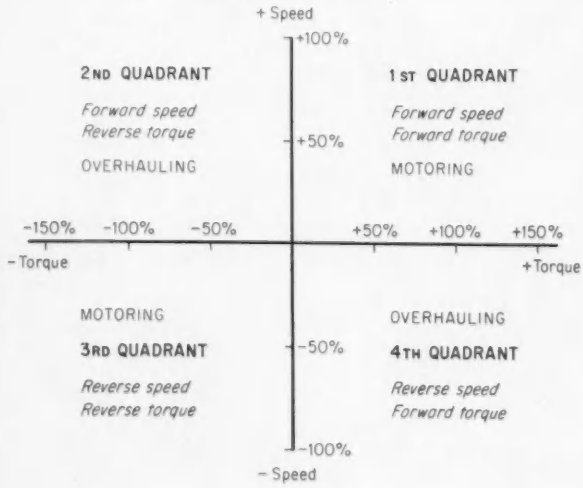
Forward direction, overhauling. Operation in this quadrant implies that the motor is delivering power back to the line. This would occur, for example, if the motor were being overdriven by a gasoline engine after being used to start that engine, or when the motor is decelerating an inertia load from some forward speed under regenerative braking. Now, mechanical power output is negative. Similarly, input power is described as negative since the motor is actually delivering electrical power rather than accepting it. To supply the needed negative or reverse torque, the field current is made negative. The negative field, in combination with the positive rotation, produces a negative back emf, according to the second fundamental relationship listed above. Since the armature must at all times remain constant and in the same direction, the regulator now acts to reverse the polarity of the applied voltage and maintain it at some value which is less than the back emf by the amount of the IR drop.

Reverse direction, motoring. Operation in this quadrant is similar to operation in the first quadrant in that the motor is now either driving a friction load or accelerating an inertia load; the direction of rotation, however, is the opposite. Mechanical power output and power input will again be positive. Torque will be negative, since the load is being driven in the reverse direction. The field current is made negative to produce this torque in conjunction with the armature current (which is still positive, of course). Generated emf is positive since both torque and rotation are negative. Therefore, the system supplies a positive armature voltage.

Reverse direction, overhauling. When operating in this quadrant the motor is either being driven in the negative direction by the load or is decelerating an inertia load from some negative speed to some lower negative speed. Power output will be negative in either case and, for the reasons explained previously, power input will be too. Torque must be positive and is produced by positive field current in conjunction with positive armature current. Back emf will be negative because of the negative rotation and positive field current. Armature voltage must therefore be reversed by the regulator and maintained at some value lower than the back emf in order to assure positive and constant armature current.

Four-quadrant operation similar to that described above for the constant-current rectifier-type control can also be obtained with adjustable voltage systems of the Ward Leonard type. Shown in Figure 4 is a comparison of the armature circuit and field circuit relationships in the two systems. Constant-torque motors are assumed in both cases.

FIG. 3. Chart showing torque-speed combinations in four quadrants of operation.



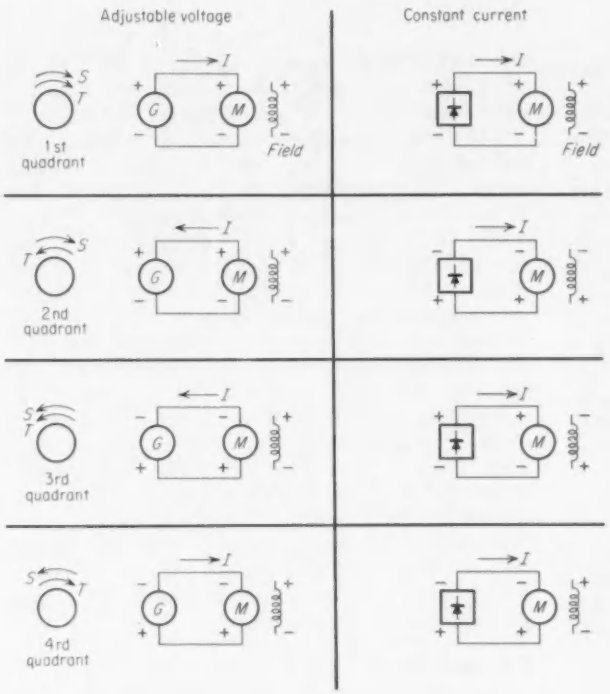
Armature rectifier

It was stated above that the applied armature voltage (which is the armature rectifier output voltage) must be negative when the motor is overhauling or decelerating in either direction of rotation to maintain armature current positive. Thus the rectifier is required to supply a reversible voltage output. The single-phase double-way rectifier circuit shown in Figure 5 helps explain how a rectifier can be made to do this. Three-phase or six-phase rectifier circuits having the reversible feature adhere to the same basic principles of operation.

Assume that the ac grid voltage for each tube can be varied from directly in phase with the anode voltage to 180 deg out of phase with the anodes. Figure 6 shows the rectifier output voltage for three phasing conditions. In each case it is assumed that the motor armature current (determined by shaft load) is sufficiently high to assure continuous tube conduction. In Figure 6A, each tube is phased almost full on. The resulting average output voltage is almost the rated positive maximum rectifier output. Maximum output for this rectifier, assuming continuous current, is 0.9 times the rms value of the ac anode voltage per tube, neglecting rectifier regulation.

In Figure 6B, each tube is phased on for approximately 100 deg. The output voltage of each tube is positive during part of its 180-deg conducting period and negative for the rest. The average output voltage is, however, still a net positive voltage, although of smaller magnitude. In Figure 6C, the tubes are phased on approximately for 30 deg and the output voltage consists of positive and negative segments of voltage. In this case, however, the net output voltage is a negative quantity.

The two voltage waves shown in Figure 6 are derived from the input transformer. Although the system here is single-phase, the two rectifiers are cross-connected to the input transformer so that their plate voltages are 180 deg out of phase. The shaded



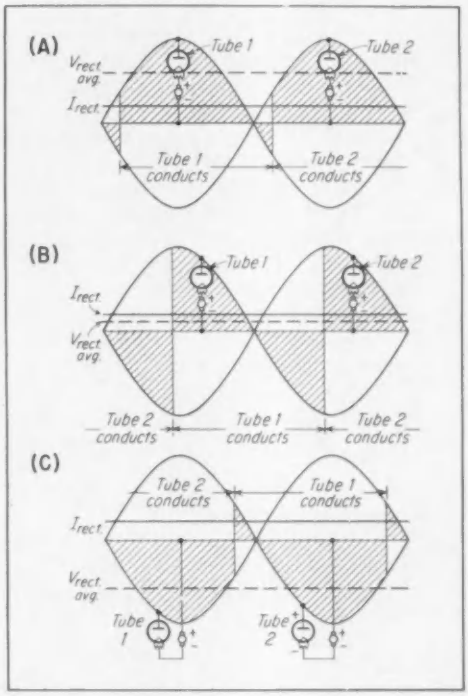


FIG. 4. Field and armature polarities for four speed-torque quadrants. Sketches at left pertain to Ward Leonard system. Those at right are for constant current operation.

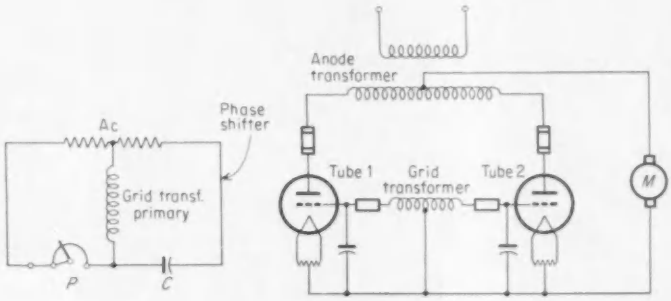


FIG. 5. Simple grid-controlled single-phase double-way rectifier with provision for adjusting the phase of the grid voltage.

FIG. 6. Rectifier output voltages for three phasing conditions. In A and B, the motor is driving the load, while in C the motor is being driven by an overhauling load.

portions of the curves indicate the time that each particular tube is conducting.

One fact should be emphasized at this point. Even when the net output voltage is negative, there will always be a positive voltage from the cathode to the anode of each tube when it is conducting. For the rectifier to develop the net negative voltage, each tube must remain conducting even when the supply voltage for that tube goes negative. During this time, the required net positive voltage across the tube itself is obtained primarily from the motor back emf which during this time will be reversed. Assisted on an instantaneous basis by the voltage induced by armature inductance, the motor must be developing a back emf which, on the average, is both negative and higher in absolute value than the negative value of the supply voltage applied to the tube. Further, for the motor voltage to be and to remain negative, while its armature current remains positive, the motor must be driven by an external mechanical torque, such as that provided by an overhauling load.

In the case of the constant-current system where the field current is capable of being reversed, a similar condition of negative voltage and positive armature current could exist on a temporary basis, during the deceleration of the motor and load from a high speed to a lower speed in the same direction.

MODIFIED CONSTANT-CURRENT SYSTEM

The basic constant-current system contains several limitations, including the following:

1. To develop rated motor horsepower, the armature current must be maintained at rated value at all times, even when the motor is running at no-load or light-load conditions. This means that the armature is subjected to rated heating and commutating conditions even when these are unnecessary.

2. A motor having both armature and field speed ranges cannot be operated satisfactorily in the field

portion of the speed range under full-load conditions. Although, as will be shown later, the basic system will permit operation above base speed under light load conditions, the driven motor will run no higher than base speed under load.

3. Since the speed regulator portion of the circuit acts entirely on field strength as a means of regulating torque and speed, the maximum speed of response is limited by the maximum rate at which the field flux can be forced to change.

To overcome these limitations, a modified version of the constant-current system has been developed, Figure 7. Two new features of the system are: voltage limit and an armature-current forcing circuit. The latter is necessary to eliminate the first limitations mentioned above. Armature current must be maintained at a relatively low value for light-shaft-load conditions and increased only as necessary to support higher load conditions.

At no-load, armature current is regulated by the current regulator at some low value. During no-load or light-load conditions, the speed regulator supplies a low value of field current, which, acting in conjunction with the controlled armature current, is just sufficient to overcome friction and windage losses. The speed regulator changes the field strength slightly as required to overcome any variations in frictional losses, thus maintaining preset speed.

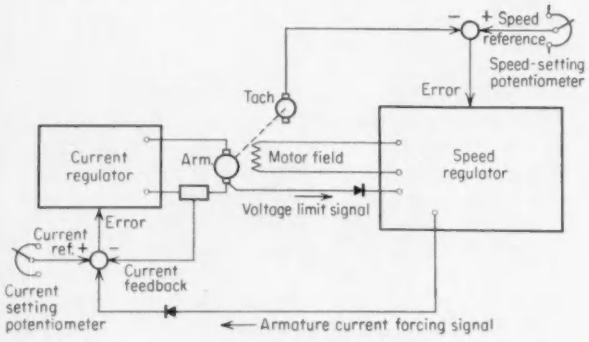
As load is applied, the speed regulator causes field current to increase. If, after full field current is reached, the resulting torque is insufficient to sustain the applied load, the speed regulator will supply a forcing signal to the armature current regulator. Armature current increases until torque developed by the motor equals the load torque. Thereafter, field current is maintained at its maximum value while the speed regulator holds speed at the preset level by making minor variations in the new level of armature current. Further increases in load torque are compensated for by the forcing circuit until maximum armature current is reached.

If an overhauling load torque attempts to drive the motor above preset speed, the speed regulator increases the field current to maximum in the reverse direction. Then, the forcing signal again comes into play to increase the armature current in the positive direction. If the overhauling torque is further increased, armature current will rise to its limit, at which time the motor delivers maximum negative torque to avoid being driven above the preset speed.

The current-forcing circuit permits the armature current to be low under light load conditions and assures that commutation of rated load current will be required only under rated field conditions. As a result, except for very light load conditions when the armature current is being maintained at a low value, commutating conditions are similar to those in conventional adjustable-voltage systems.

Another benefit of the current-forcing circuit is that with low armature currents, the speed regulator must apply more field current to supply even the relatively light no-load frictional losses. For example, if no-load torque required is 10 percent of rated and if the armature current is being held at 20 percent of rated, the speed regulator will have to supply 50 percent of rated field. The result is much faster response to increased load torque since the field is already at half strength. Figure 8 shows armature current–field current–torque relationships in the modified constant-current drive.

FIG. 7. Block diagram of modified constant-current system. The voltage limit takes over only when the generated back emf approaches a present internal reference voltage.



Voltage limit

One function of the voltage-limit circuit is to prevent excessively large and possibly damaging values of back emf. A second function is to permit operation in the field portion of speed control.

As in the conventional adjustable-voltage system providing both armature and field control, it is necessary to limit the field strength of the motor when running above base speed. Were full field applied at such speeds, excessively high back emf voltages would be generated. Full field applied to a motor rotating at four times base speed, for example, would cause a voltage of four times rated to be generated.

The voltage-limit circuit compares the back emf generated by the motor with a reference voltage representing rated value. When the back emf approaches rated value, this circuit provides an output signal which overrides the speed regulator insofar as field current is concerned. It will reduce the field current as required so that the rated armature voltage is not exceeded, but will not prevent the speed regulator from performing the armature-current forcing function (required to maintain output torque in the field-range region).

The second function of the voltage-limit circuit is to permit operation in the field speed range. It is fairly easy to make the motor operate above base speed under no-load conditions even without the voltage-limit function if the speed-control potentiometer is very slowly advanced from zero to a value calling for such a speed. However, as shaft load is applied, several undesirable events take place.

With increasing load, the speed regulator causes the field current to increase. If the applied load torque is high enough, the increase in field current will continue until rated value is reached. Since the motor is assumed to be rotating above base speed, full

field current will cause a back emf above rated to be generated. Remember that the armature current rectifier is capable of producing a maximum output voltage only slightly above rated motor armature voltage. Because of this limitation, and because a rectifier is a one-way device, armature current must cease when back emf exceeds rated terminal.

If the shaft load is maintained after current stops, the motor speed decreases and the generated back emf drops proportionally until base speed is reached. At that point, the rectifier again can pass current through the armature. The speed continues to drop slightly until the armature current increases to the point where (in conjunction with the field current which is being held at rated by the speed regulator) it can supply the load torque demanded. Then, several conditions are noted:

1. The motor is not running at the preset twice base speed. Rather, it is running approximately at base speed.
2. Since the speed regulator is not satisfied, it is delivering full field to the motor in an effort to speed it up. However, the motor cannot speed up, since this would increase the back emf again, lowering the armature current and dropping the motor output torque below that demanded by the load. It should be noted at this point that current forcing would have no effect and constant current would not be maintained in the armature.
3. If load torque is decreased, the speed would increase slightly with a like effect on back emf. This would decrease the difference between rectifier armature voltage and generated emf to the point where only a small armature current would flow. The motor would remain at base speed while the speed-control potentiometer is still calling for twice base speed.

It must be concluded from this example that, without some additional intelligence, the constant-current system could not operate successfully in the field range and could easily become "locked out" at base speed. The second function of the voltage limit circuit is to supply this intelligence by overriding the speed regulator whenever the latter tries to apply a field current which would cause the armature to produce a back emf above rated value. Again, the voltage limit function in no way interferes with the armature-current forcing function. It does limit the back emf of the motor so that the armature current rectifier is always capable of supplying enough voltage to circulate any armature current demanded by the load within the rating of the motor.

APPLICATIONS

The constant-current drive has two benefits heretofore obtainable only in the Ward Leonard type of drive. These are regeneration and reverse rotation without reversing contactors. Other features inherent in the constant-current drive include: tachometer feedback for close speed control; current control and current limit; forward and reverse voltage limiting; circuit preconditioning, permitting the drive to be started or stopped at any speed; ability to supply, without circuit change, motors having armature range only or both armature and field range.

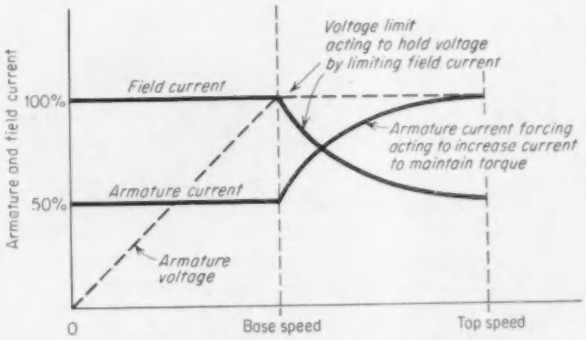


FIG. 8. Characteristic curves for modified constant-current system with constant-torque load.

The regeneration feature opens up new application possibilities for the rectifier-type of motor control. While readily providing controlled acceleration either by means of current limit or time rate, such drives heretofore could effect controlled deceleration of a sort only with difficulty, and smooth deceleration not at all. "Quick-slowdown" circuits incorporating intermittently applied dynamic braking have been used, but have the disadvantage of a tapered rate of deceleration. Deceleration of large inertia loads has required a stepped form of dynamic braking with additional sensing and heavy magnetic circuitry.

The constant-current system inherently provides both positive and negative torque control. Positive torque is obtained for acceleration and negative torque is automatically supplied, if required, for deceleration. Time-controlled acceleration and deceleration can be furnished by interposing a small linear time acceleration and deceleration circuit between the speed-setting pot and the speed-regulator input.

One example of the possibilities offered by the regeneration feature is cutting a material being processed into accurate lengths. A wheel riding on the surface of the material operates through a counting mechanism to provide the measurement function. The material is paid out at high speed until some short time before the cut which is to be made at low speed. The counting mechanism operates three limit switches, one just prior to the cut, one at the time the cut is to be made, and one immediately after the cut. The first calls for low speed, the second operates the cutting knife, and the third calls for high speed again. It is apparent that to obtain the highest rate of production the motor's maximum rates of deceleration and acceleration must be utilized. The length of time at low speed must be minimized. It is apparent, also, that the times required to accelerate and to decelerate are minimized if the rates of acceleration and deceleration are held constant at the maximum values.

The constant-current drive meets this application requirement because it can control the motor torque

at its maximum safe value. This is true whether the motor has armature range only or both armature and field range.

Reversing drives

Reversal in the constant-current system is accomplished simply by changing the speed reference signal from positive to negative. This characteristic:

1. Eliminates an armature reversing contactor.
2. Eliminates the dynamic braking portion of the reversing sequence that is required on drives with the free-wheeling type of armature circuit.

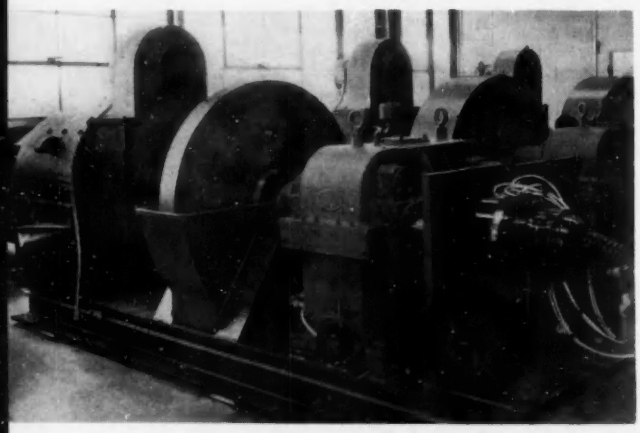


FIG. 9. Three 200-hp constant-current drives installed in aircraft-generator testing laboratory.

3. Allows use of small limit switches or other low-power switches to initiate reversing.
4. Permits continuous adjustment of speed from forward to reverse with a low-wattage, single-plate speed-control potentiometer.

An application illustrating the value of these characteristics is a center-driven w eel lathe. Here it is desired during the first part o. the cutting cycle to bring the first tool from the outside rim of the wheel to the center, gradually increasing the lathe speed in accordance with a programming signal to maintain a constant surface cutting speed. When the tool is at or near the center of the work-piece, it is necessary to withdraw the first tool, reverse the drive and bring a second tool in contact with the work. As the second tool proceeds from the center to the far end of the work piece, the lathe drive is programmed from high speed to low speed, again for the purpose of maintaining constant surface cutting speed. A small limit switch could initiate reversal without the operation of a larger reversing contactor. Speed adjustment periods could be controlled by a cam-operated low-wattage potentiometer.

This drive has been successfully applied to the testing of aircraft-generator voltage regulator and protective systems. Figure 9 shows three 200-hp drives installed in one testing laboratory. In this installation, each of the motors drives through a gear box having dual output shafts making possible the testing of parallel-connected generators. General requirements include good no-load to full-load regulation, minimum speed dip on application of load, minimum overshoot on removal of load, and fast settling-out time.

Note that each motor mounts a flywheel to simulate the inertia of a jet engine. The flywheel acts to reduce the transient speed dip with load and to eliminate possible interference between the aircraft regulating system being tested and the drive regulating system. Not shown is a simple load-compensating circuit to further reduce the speed dip to a very low value. Applications similar to the one described above have been made to 40-hp and 125-hp drives. Ignitron rectifier power circuits were used in each case to supply the motor armature.

General-purpose applications

Many general-purpose industrial applications which do not require the special features of regeneration and easy reversing can be satisfied on both a functional and economic basis by the constant-current motor-control system. Certain machines having substantially constant-torque loads depend on speed adjustment rather than speed regulation. Printing presses are an example.

In a typical installation, speed indication is provided by a tachometer calibrated in papers per hour. Fast and slow buttons control a motor-operated potentiometer to adjust the motor speed and thus obtain the desired paper rate. Slow speed is required for threading the paper through the press. The modified drive is capable of plus or minus 1 percent regulation when such accuracy is required and plus or minus 5 percent when speed adjustment rather than speed regulation is demanded. The lower accuracy permits rapid adjustment during installation and does not detract from the ability of the drive to satisfy functional requirements. The principle involved here is one of matching the drive to the driven equipment.

A broad group of processes demands coordination of tandem-operated machines. The manufacture of rubber, paper, film, glass, wire, plaster board, etc., involves a number of continuous processing steps that must be coordinated with respect to speed, tension or position. The speeds of adjacent sections must be closely matched or synchronized.

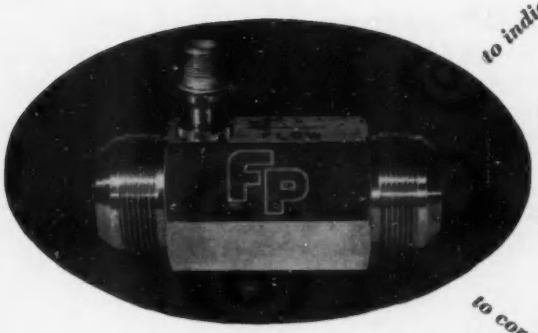
The ignitron constant-current drive is better equipped to meet these requirements than its adjustable-voltage counterpart. Tachometer-follower operation for close speed coordination, for instance, is readily provided, since every standard constant-current drive operates on tachometer feedback. Speed coordination during slowdown and speedup is assured because of the automatic regenerative braking feature. Position synchronization can be readily achieved by adding synchros to each motor and a small discriminator panel to the follower unit.

PANEL FLOW RATE INDICATOR

to indicate flow

to indicate steady state flow condition

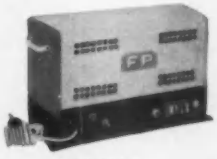
IN-LINE DIGITAL INDICATOR



to totalize flow for batch processes

DIGITAL TOTALIZER

to convert transient flow for analog output



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DIGITAL TOTALIZER: Provides integrated flow information accurate to ½%.

FREQUENCY MULTIPLIER-CONVERTER: Extremely rapid response to transient flow signals. Sampling of eight points per cycle provides more information than conventional means.

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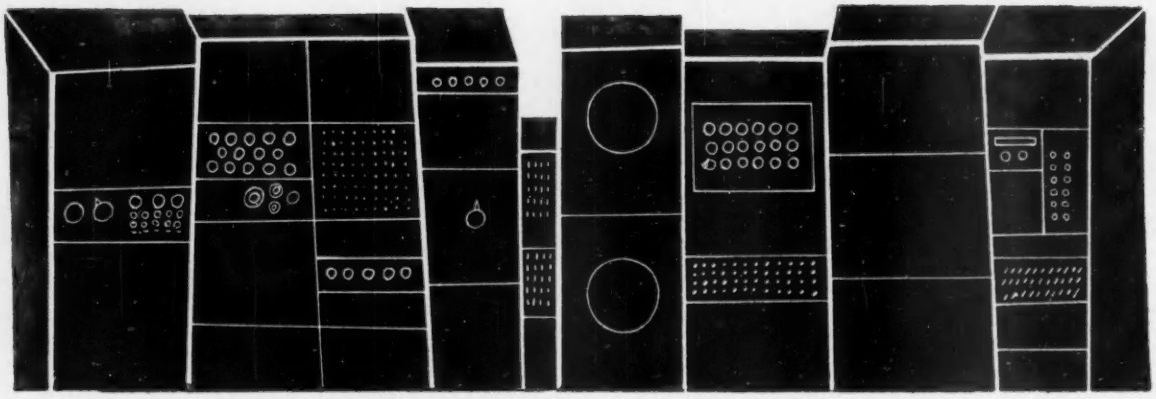

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How Input/Output Units Affect Data-Processor Performance

THE GIST: In weighing the performance characteristics of an electronic data-processing machine, one is apt to focus attention on the arithmetic, logical, and control sections—the "heart" of the machine. What is found out about these units may label the entire system as far as speed, capacity and flexibility are concerned. Actually, however, consideration of computing units alone does not constitute a valid evaluation of data-processor performance, since it neglects input and output devices, which greatly influence the workings of the overall system. It is the balance between input/output and the central unit that determines system effectiveness. In line with the "weakest-link" theory, a system can be no faster, no more capacious and no more flexible than the devices associated with it.

In this article, the author describes the various types of input and output units of current interest in the data-processing field. Special attention is given to those traits that enhance or restrict the operation of the arithmetic units to which they are connected. The intimate link between data processor and input/output devices is confirmed by a case study of a basic computer which in the span of a few years grew from a "medium-performance" to a "powerful" unit simply by the refinement of input/output equipment.

JAMES GIBBONS
Price Waterhouse & Co.

In the development of business-data processors the emphasis was placed initially on expanding the instruction repertoire and increasing the flexibility of internal manipulation in order to accommodate the non-uniformity inherent in classifications of business information. Various methods were devised for handling mixed alphabetic and numerical data such as names and part numbers, and also for processing information in which the number of items comprising records and the length of these records themselves varied.

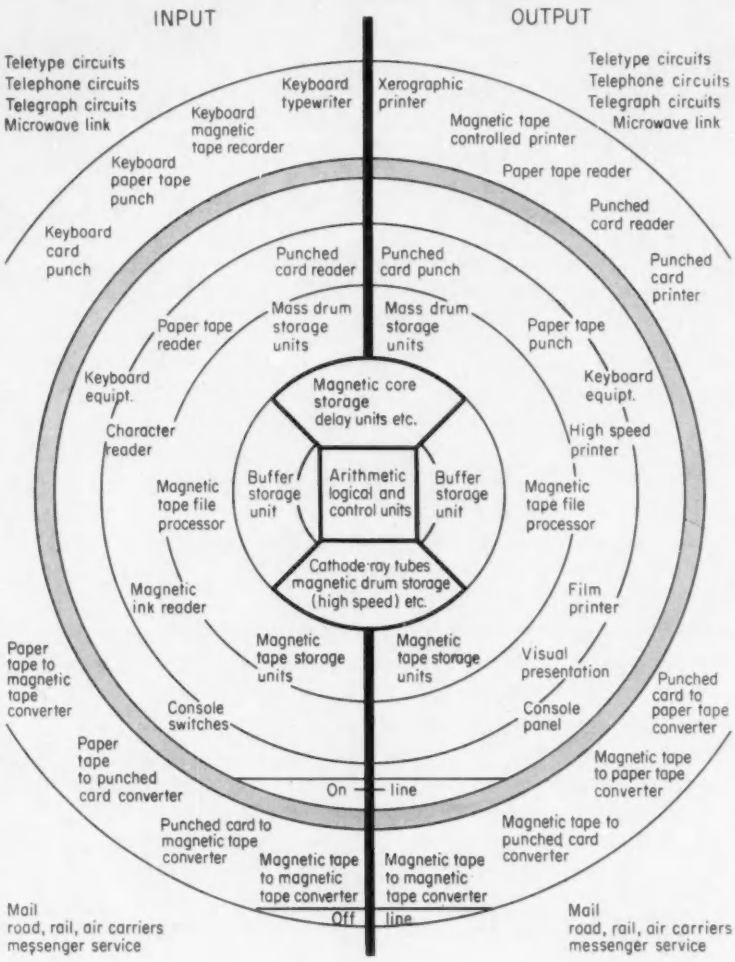
Once this had been accomplished successfully, as in the case of the Remington Rand UNIVAC I, attention turned to increasing the facility for making information available to the processor, and for communicating and displaying processed information in useful form. It had become evident that the successful use of business-data processors depended as much on efficient input and output facilities as it did on the capability of the central processor.

General considerations

Classification of input/output equipment. Theoretically, it may be desirable to evaluate the various input/output units by type, tabulating their characteristics for direct comparison. However, such an analysis does not truly represent the capabilities of working equipment. Manufacturers of data-processing equipment have tended to develop unique input and output facilities, especially the directly connected variety. The products of magnetic-tape-handling equipment manufacturers such as Potter and Ampex have been incorporated into data processing systems offered by other manufacturers. Most manufacturers, however, prefer to retain control over the input and output units, and to design their entire systems with these as basics.

Table I gives the various categories of input and output equipment. At the center, the internal functions of the data processor and the attendant internal memory and buffer registers are designated. Buffers are an important link between input/output units and the central unit. With buffers, an overlapping of input, internal processing, and output operations (an integral part of high-speed operation) is usually possible, especially if the processing cycle is not lengthy. Buffer registers take the form of delay lines, magnetic drums, magnetic cores, and shift registers or flip-flop arrays. They may be contained in the main frame, as in UNIVAC, or in separate units, as in the IBM 709 Data Synchronizer. In UNIVAC I there are two 60-word registers in the memory delay line storage element, each storing 720 digits or one

Table I — Organization of Data-Processor Components



block of information on a tape reel. In UNIVAC II these registers take the form of magnetic cores.

Proceeding outward from the center, the diagram in Table I shows the directly connected units, including magnetic-tape devices, file storage units, sorters, card readers and punches, and high-speed printers. These are usually connected to the central processor. As can be seen, however, many input/output units perform dual roles. It is possible to consider these devices "on-line," performing one role at one level of efficiency, or operating "off-line" as peripheral units of quite another level.

Finally, the table shows various classes of peripheral equipment associated with the preparation of information for the on-line elements of the system, and the arrangement and presentation of processed information in usable form. These include conventional punched-card and paper-tape equipment, and the various converters to and from magnetic tape. Peripheral equipment can be considered to be that equipment found at points of transaction origination not under the direct control of the data-processor. These would include cash registers, production recorders, etc., and paper-tape and punched-card communications systems.

Structure of business data

The characteristics of business data have been discussed in previous articles in this series. However, since these characteristics have their first and perhaps most direct impact on input/output equipment, it is appropriate here to consider them in detail. Simply speaking, business data exist in files of blocks of records, each of which in turn consists of items made up of words. The words consist of characters formed from various codes, usually configurations of binary digits or bits. The sizes and frequencies of these structural elements vary greatly among the various kinds of business data (inventory records, payrolls, bank accounts, customer histories, etc.), and thus require considerable flexibility in the input/output devices as well as in the data processor.

Files can be held in magnetic tape, or in other mass storage elements such as file drums and disks. In data-processing flow, blocks of records may be held for processing in a working area of internal storage. Words (or items) are usually of such size that they can be contained in registers or accumulators in the central unit.

Except for the basic representational element, or bit, there is considerable freedom provided throughout the range of data processors in treating the structural elements of data. For example, there are fixed word and record length systems, variable word and record length systems, and free word length systems. In several systems it is possible to use both four-bit hexadecimal or six-bit (or eight-bit) alphanumerical representation in the same machine. Another system allows pure binary numerical representation or conventional six-bit alphanumerical characters. This flexibility reduces demands made on the input/output equipment, particularly where editing and arrangement are concerned. In systems where the structural elements of the data tend to be fixed, there is a need for editing and arranging functions in input/output equipment or for an initial arrangement of data in a prescribed form in a machine-sensible media such as punched tape or cards.

Hardware and media

Initial transcription into machine-sensible media. There are several media, including punched tape, punched cards, and perforated tags, and several writing techniques including magnetic and fluorescent inks that can be read automatically. Usually the initial impression is through a keyboard, which may be associated with other equipment, including typewriters, key punches, adding machines, and communications devices. Other techniques are hole-punching, done manually by means of spot punches, and mark-sensing, in which pencil marks on tabulating cards are converted into hole data by punched-card equipment. Punched paper tape with from five to eight channels can be produced as a by-product of normal machine-writing operations. The five-channel tape, usually referred to as "common language" tape, can be used directly for wire communications; the six-,

seven- and eight-channel tapes for machine control signal channels, character representation, and checking.

In the RCA BIZMAC system and in the NCR 304 system, the initial input medium is punched paper tape. In most other systems the initial input medium is usually punched cards.

Punched paper tape as input media. The term integrated data processing, or IDP, was developed at U. S. Steel Corp. in connection with its office-methods research work to link together various business machines. First announced in 1954, IDP has stirred considerable interest. To many it may be a substitute for or an adjunct to electronic data processing. It did result in wide acceptance of punched paper tape as a record storage and communications medium in business, and stimulated the production of punched-paper-tape readers and punches, and of bookkeeping, accounting, and calculating machines with tape attachments. Most important, IDP was responsible for highlighting the problems associated with recording information in some machine-sensible form at the source of transaction information. It will probably result in better techniques for entering information into data-processing systems, along the lines of IBM's APR (Automatic Production Recording System), which essentially relates the handling of information in control functions to its subsequent use in accounting applications.

Five-channel tape in IDP systems creates problems of translating, editing, and checking when used as input to an electronic data-processing system. To varying degrees these problems have been solved by an initial conversion run to decode the five-channel language while initial editing and checking operations are going on. Paper-tape/magnetic-tape converters, such as those under development for UNIVAC and UNIVAC Scientific systems, provide for five-, six- or seven-channel conversions with automatic code translation and limited editing operations. The processors' output tapes (other paper tape or magnetic tape) are provided with the codes and formats necessary for further operations for communications facilities.

RCA and NCR take another approach to the use of paper tape as the initial machine-sensible record. These companies promote paper-tape recording facilities featuring the same code used by the internal processor. The conversion of paper-tape information then becomes a literal translation of punched holes to electronic impulses and the required editing a matter of format control—usually a part of magnetic tape processing.

Punched cards as input media. Punched cards have gained almost universal acceptance as both machine-sensible media and as informational documents. As the latter, they are used as checks, production records, sales tags, restaurant menus, and soap coupons. They also are an excellent means for entering information in a data-processing system. Punched-card equipment is marketed in this country by IBM, Remington Rand Div., and Underwood Samas Corp. Remington Rand's 90-column punched cards are used with its UNIVAC line of data-processing equipment. IBM's 80-column punched cards are widely used as input media by many data-processing systems, including the Remington Rand UNIVACS, RCA BIZMAC, Burroughs Datatron and DATAmatic 1000.

There are two main reasons for the great acceptance of IBM punched cards as input media. First is the relatively wide use of the cards in existing punched-card installations; second, IBM punched-card equipment, with its electrical card-sensing mechanisms, lends itself to direct connection to other data-processing elements.

Tables II and III illustrate the range of card-handling equipment associated with electronic data-processing systems. While card-reading speeds vary from 150 to 1,000 cards per minute, card-punching speeds remain in the 100-card-per-minute area,

TABLE II—INPUT DEVICES

Punched Card Readers (On-Line)
Punched Card to Magnetic Tape Converters (Off-Line)

Manufacturer	Model	Maximum Number On-Line	Type of Card, Columns	Maximum Card Reading Speed	Checking Features	Magnetic Tape Unit Used Off-Line	Magnetic Record Size
Burroughs Corp.	Datatron	7	80	240 cpm		none	
DATAmatic Corp.	1000	0	80	900 cpm	dual reading	model 1100	fixed block
International Business Machines Corp.	305	1	80	125 cpm	dual reading	none	
	650	3	80	200 cpm		none	
	705	100	80	250 cpm	dual reading	model 727	variable block
	709	3	80	250 cpm		model 729	fixed block
National Cash Register Co.	304	1	80	1,000 cpm	dual reading	model 330	variable block
Radio Corp. of America	Bizmac	none	80	400 cpm	dual reading	3100 series	variable block
Remington Rand, Division of Sperry Rand	File Computer 0	up to 33	80 or 90	150 cpm	dual reading		fixed block
	" " 1	up to 33	80 or 90	150 cpm	dual reading		fixed block
	Univac 1	none	80 or 90	240 cpm	dual reading	Uniservo I	fixed block
	Univac II	none	80 or 90	240 cpm	dual reading	Uniservo II	fixed block
Alwac Co.	III—E	1	80	200 cpm		none	fixed block
	800	10	80	200 cpm		none	fixed block

TABLE III—OUTPUT DEVICES

Card Punches (On Line)
Magnetic Tape To Punched Card Converters (Off Line)

Manufacturer	Model	Maximum Number On-Line	Type of Card, Columns	Maximum Card Punching Speed	Checking Features	Magnetic Tape Unit Used Off-Line	Magnetic Record Size
Burroughs Corp.	Datatron	7	80	100 cpm	DPBC	none	
DATAmatic Corp.	1000	none	80	100 cpm	DPBC	model 1100	fixed block
International Business Machines Corp.	305	1	80	100 cpm	DPBC	none	
	650	3	80	100 cpm	DPBC	none	
	705	100	80	100 cpm	re-read check	model 727	variable block
	709	3	80	100 cpm		model 729	fixed block
Alwac Co.	III E	1	80	100 cpm	DPBC	none	
	800	10	80	100 cpm	DPBC	none	
National Cash Register Co.	304	none	80	100 cpm	re-read check	model 330	variable block
Radio Corp. of America	Bizmac	none	80	150 cpm	re-read check	3100 series	variable block
Remington Rand, Division of Sperry Rand	File Computer 0	up to 33	80 or 90	150 cpm		yes	fixed block
	" " 1	up to 33	80 or 90	150 cpm		yes	fixed block
	Univac I	none	80 or 90	120 cpm	re-read check	yes	fixed block
	Univac II	none	80 or 90	120 cpm	re-read check	yes	fixed block

DPBC = Double Punch & Blank Column Detection

TABLE IV
MAGNETIC TAPE UNITS FOR DATA PROCESSORS

Manufacturer	Model	Maximum No. of Units On-Line	Forward Speed, in. per sec.	Rewind Speed, in. per sec.	Recording Density, char. per in.	Recording Mode
Burroughs Corp.	**Datatron**	10	60	120	100	FW, FB
DATAmatic Corp.	**1000***	100	100	100	600‡	FW, FB
International Business Machines Co.	**650**	6	75	500	200	VW, VB
	705†	100	75	500	200	VW, VB
	709‡	48	75	400	200	FW, VB
International Computer Co.	**Diana**	One tape unit used only as a dump to clear the drum for further applications. Cannot be interrogated.				
Alwac Co.	**III E**	10	100	—	100	FW, FB
	800	100	100	—	200	FW, FB
National Cash Register Co.	**304**	64	100	—	150	FW, VB
Radio Corp. of America	**Bizmac**	15	80	80	200	VW, VB
Remington Rand, Division of Sperry Rand	**Univac I**	10	100	100	120	FW, FB
	" II	16	100	100	200	FW, FB

* Each 8 tape units require a control unit. The first 8 operate directly from the computer.
† Each 10 tape units require a control unit. If TRC's are used, 8 tape units require a TRC.
‡ Each 16 tape units require a data synchonizer.
‡ Quoted at 60,000 decimal digits/sec.

FW = Fixed Word
VW = Variable Word
FB = Fixed Block
VB = Variable Block

a manifestation of the mechanical inertia in punch-die operation. From the many manufacturers represented, one might conclude that punched cards rank near punched paper tape as "common-language" media.

Magnetic tape units. Table IV indicates the current status of available magnetic-tape units associated with electronic data-processing systems. Within the past year two manufacturers have announced magnetic-tape units with immediate read-during-write operations for fast error detection. This read feature provides a parity-bit check for every character immediately after it has been written on tape, and this increases the reliability of the tape recording process. Systems having this feature include the NCR 304 and the IBM 729 magnetic tape units of the IBM 709.

High-speed printers. The development of mechanical high-speed printers has proceeded in two directions. One is toward the so-called "on the fly" multiple print wheel printers of the Shepard type, used with the RCA BIZMAC and the Remington Rand UNIVAC. These operate at 600 lines per minute, usually with 120 characters per line. The other is toward matrix printers, in which characters are formed by varying combinations of 5-by-7 arrays of wire points. These are used in IBM systems. Printing speeds are 500 or 1,000 lines per minute. Burroughs has developed the G100 card-actuated wire printer operating at 900 lines per minute.

Printing speeds beyond these will be provided by nonmechanical printers. A typical example is the RCA BIZMAC electronic printer. This consists of three units: Ultratype camera, film processor, and Electrofax printer. Information from magnetic tape is displayed on a cathode-ray tube as characters arranged in page format, then photographed. The character display rate is 2,000 per second, and the average page rate for 35-mm film advance is 20 per second. After the film has been processed, copies are reproduced in the Electrofax printer at the rate of 6 in. of paper per second (any width). Multiple copies can be procured by frame repetition.

Mass storage devices. Large-scale addressable storage devices can, in a certain sense, be considered as input and output. The following is a list of such storage devices:

1) *Datafile—Burroughs Datatron.* Multiple type bin with 50 tapes, each 250 ft in length. Capacity 22 million digits per Datafile. A maximum of 10 can be used in a single system.

2) *DATAmatic — DATAmatic 1000.* The magnetic-tape system permits high-speed search of 50,000 blocks (62 words) per tape unit at a rate of 120,000 characters per sec.

3) *IBM Ramac.* This 50-disk magnetic storage system in the 650 magnetic drum data processing system has capacity of 6 million decimal digits. It is also supplied as part of the 305 Ramac, providing 5 million digits of alphanumerical storage.

4) *IBM Magnetic Drum 733-734.* A 60,000-character magnetic drum is available in the 705 and 709 systems. Up to 30 type-734 drum storage units can be used in the 705. In the 709, type 733 drums are furnished in two capacities—8,197 or 16,384 words (36 binary digits).

5) *International Computer Co. Drum.* Up to 33 file drums can be incorporated in a single DIANA system. Each drum has a capacity of over 2 million characters, alphabetic or numerical.

6) *Remington Rand UNIVAC File Computer.* Up to ten storage drums can be included, each with a capacity of 180,000 digits.

A storage device can be classified as an input-output element if its information must be transferred to another storage element before the data can be manipulated. The RCA BIZMAC storage drums for program storage falls under this classification. The programs stored in the two drums comprising the memory have a capacity of 32,768 characters. Transfer to an 8,192-character core storage at a character rate of 100,000 per second takes place when stored instructions are moved into the core memory for processing.

IBM 650 system development

The choice of the input/output devices is vital in establishing a data processor's performance. As a case in point, consider the IBM 650 which, when introduced, was a machine of moderate performance. As its development continued, faster and more capacious input/output accessories were made available, so that today the 650, with the proper auxiliaries, may definitely be classed as "powerful".

The initial specifications for the IBM 650 were for a machine that would be intermediate in cost and speed, simple to operate, and self-checking (through the use of a biquinary code). The IBM 650 that emerged in 1954 used 80-column punched cards and a 533 Read-Punch Unit for input/output. The 533 provides for card handling in two separate feeds: the read card feed operates at a maximum speed of 200 cards per minute, and the punch feed operates at a maximum speed of 100 cards per minute. Two 80-column reading stations are associated with the read feed: the second handles normal reading, and the first senses control changes. The punch feed is equipped with a set of reading brushes which are used for double punch and blank column error detection. The 533 has no provision for reading the punched card output into the computing circuits, however. A control board relates card columns and the internal

input/output buffers located on the magnetic drum.

This original grouping required additional punched-card processing facilities, including sorting, collating, and printing. Apparently many users required more input/output versatility to eliminate additional card handling and to provide multiple accessibility.

In 1955 IBM announced additional accessories, including magnetic-tape units, and facilities for handling up to three Model 533 read-punch units and Model 407 accounting machines (150 line-per-minute printers) in any combination. Three input/output synchronizers, involving unaddressable drum areas and cable connections, provide the means for associating the additional card-handling equipment. These conventional cable connectors make it possible to operate the 407 Accounting Machine either independently or on-line. The synchronizers handle read or write instructions.

The IBM 650 magnetic-tape input/output uses the IBM 727 tape units developed for the 700 series of equipment. There is thus compatibility in code structures between the 650 and the 705. Up to six tape units can be incorporated in a single 650 system through the use of a 652 tape control unit. There is no provision for simultaneous reading while writing. Necessary to the operation of the tape units is the 653 auxiliary unit, containing a 600-digit magnetic-core buffer storage. This provides means for transferring from one to 60 words between the tape units and the magnetic drum. The 653 can be used independently as well.

In 1956, the manufacturer announced the Ramac random-access disc storage. Currently up to four Ramac units, each with a capacity of 6 million decimal digits, can be provided in a single 650 system. To increase the flexibility of the system with the Ramac units, there is also provision for up to ten type 838 stored-data inquiry stations, which are essentially typewriters for keying interrogations and printing selected storage locations. Another card-reading and punching unit for the 650 also was made available in 1956. This, the 537 card read-punch, provides facilities for reading and punching the same card and is a single-feed device operating at a maximum speed of 155 cards per minute. The 537 can be used as part of any combination of up to three card-handling units for input/output. Associated with the single feed are two 80-column reading stations, a punch station, and a punch-reading station. A control panel controls card operations.

Thus, in just three years, the IBM 650 has developed from essentially a subordinate unit in a punched-card system to a flexible electronic data-processing system with a wide range of input and output. Table V shows equipment combinations possible.

Input/output of small systems

Small systems may be identified by their limited resources for handling input/output equipment. This might be illustrated by comparing the LGP-30 (Royal Precision Corp.) with the Datatron. The LGP-30 is a magnetic-drum computer of 4,096 words of 30 binary digits (plus sign) capacity. Although the LGP-30's words are nine-tenths as long as Datatron words, the two systems are essentially comparable as to storage capacity. The Datatron drum operates at 3,570 rpm, the LGP-30 drum at 3,600 rpm. Average access time of each is 8.5 millisec, though the Datatron high-speed loop has an average time of 0.85 millisec.

Despite roughly comparable computing sections, there is no similarity between input/output facilities (Datatron's punched cards, paper tape and magnetic tape, and LGP-30's Flexowriter keyboard and paper-tape equipment). This difference is reflected in both price and applicability, of course. The LGP-30 was designed as a computational facility in engineering environments where problem definition comprises the largest part of the total computational time. Datatron and other business-data processors are designed for essentially repetitive work loads and hence require emphasis on automaticity.

The Underwood Elecom 50 is a unique, programmed, multi-register accounting system with considerable flexibility. A special 10-key entry is provided for variable data and a special row of keys is assigned to program selection. The 2,400 steps are coded on the interchangeable program control belts. A paper-tape reader and a tape punch (five channels) for input and output permit continuous updating. Usable output is derived from the printing and carriage mechanisms of modified Underwood accounting machines. A main printer and a slave unit have output speeds of 20 digits per second of computed data and 14 digits of descriptive information. Arithmetic operations are carried out by means of a 100-register magnetic disc containing 100 ten-digit words.

The Stewart-Warner electronic data processing unit is a stored program system utilizing a small magnetic drum for program storage and a magnetic card reader for external memory. The unit provides storage space for up to 6,000 cards. Each card contains ten fields comprising 640 alphanumerical characters. Input is through a Flexowriter typewriter and tape reader; the latter is also used with a tape punch for output.

The reader accepts magnetic cards (inserted manually) at a character rate of 60 cards per second. A man-

TABLE V—IBM 650 SYSTEM SPECIFICATIONS
(as of Nov. 1, 1956)

Catalog No.	Description	Function or Specification
650	Console — 1	1,000-word drum storage — system control
	Console — 2	2,000 word drum storage — system control
655	Power unit	Power supply
653	Storage unit — A2	High-speed buffer — floating demical point
	A3	High-speed buffer — indexing registers
	A4	High-speed buffer — floating decimal and indexing registers
	B1	High-speed buffer — immediate access storage
	B2	High-speed buffer — immediate access storage + floating decimal
	B3	High-speed buffer — immediate access storage + indexing registers
	B4	High-speed buffer — immediate access storage + floating dec. + ind. reg.
	650 with tapes — C1	High-speed buffer — immediate access storage
	650 with tapes — C2	High-speed buffer — immediate access storage + floating decimal
	650 with tapes — C3	High-speed buffer — immediate access storage + indexing registers
	650 with tapes — C4	High-speed buffer — immediate access storage + floating dec. + ind. reg.
652	Control unit — A1	Circuitry control for tape only
	B1	Tapes and Ramac — Ramac only
	B2	Tapes and Ramac — Ramac + 1 inquiry buffer
	B3	Tapes and Ramac — Ramac + 2 inquiry buffers
	C1	Tapes and Ramac — Ramac + tapes
	C2	Tapes and Ramac — Ramac + tapes + 1 inquiry unit
	C3	Tapes and Ramac — Ramac + tapes + 2 inquiry units
727	Magnetic tape drive	Input — output
533	Card read punch	Input — output
537	Card read punch	Input — output (punching into input card)
407	Printer — A1	Input — output
	A2	Input — output
355	Ramac file	Random access storage (6,000,000 digits)
838	Inquiry station	Inquiry and output
774	Tape data selector	Direct output (off-line tape to printer or punch)
747	Power unit	Power supply for 774
	Alphabetic device	Interpreting device from storage to output

ual keyboard handles the entry of quantitative information and the control keys. As many as six outputs may be provided, including the Flexowriter, paper-tape punch and automatic adding machines. A feature of the machine is the loading of operating programs from magnetic cards.

Interrelation of input/output equipment and the central unit

The input/output hardware associated with most data processors highlights the compatibility problems involved, particularly when punched-card equipment is tied into electronic data-processing equipment. These problems are due to the differences between the punched-hole coding and the internal system, to the necessity for organizing data in card form as to internal word and record length, and to the checking features, which are an important consideration in transferring data from one medium to another. A typical solution is illustrated by reference to the Burroughs Datatron system.

A Model 500 card converter, used principally in scientific computation, equips the Datatron 205 to handle IBM punched-card equipment by connecting a card reader, card punch, or line printer. An alternate method of adaptation is the Cardatron system, which is capable of handling up to seven IBM punched-card devices on-line, simultaneously. In the Cardatron system are a control unit, plus up to seven input and output units in any combination.

The characteristics of the Datatron system relating to punched-card input and output are as follows:

1) A Datatron word is composed of ten decimal digits plus a high-order sign digit. The 8-4-2-1 system of hexadecimal four-bit notation is used. Two four-bit characters make up a single alphabetic character.

2) The magnetic-drum storage comprises 20 circumferential bands, each storing 200 words. Average access time is 8.5 millisec. Four additional high-speed bands contain 20 words each (repeated ten times). The average access time to a word in a high-speed loop is 0.85 millisec.

3) Block transfer instructions are available to transfer 20 word blocks from main storage to high-speed loops or back again, at a rate of 1.7 millisec per block. Hence 20 words may be considered as a basic record size.

4) An eleven-digit *D* register for transferring data is not under program control. The Cardatron control unit communicates with the Datatron storage for input via the *D* register.

5) The accumulator of *A* register of eleven digits is the means by which the Datatron communicates with the Cardatron control unit for output.

The use of punched-card equipment in a Datatron system necessitates translation between the internal language (eleven-digit numerical words) of the Datatron, and the external (80-column) punched cards or the (120-character) line printers. The editing and arranging is performed by buffer drums associated with each input and output unit. These buffer drums also do the time sharing among the punched-card machine—the transfer time of a buffer drum from or to Datatron varies between 20 and 40 millisec while a 150-line-per-minute printer takes 400 millisec for a printing cycle. Hence it would be theoretically possible to keep ten-line printers operating at full speed.

Each buffer drum contained in an input or output unit is 2 in. in diameter and rotates at 21,600 rpm. The drum contains one information band and four format bands, each 315 digits long. A card column is considered to contain two digits, or a maximum of 160 digits per card. By the use of editing techniques, each card can be expanded to as many as 28 words or compressed to as few as one. Information in each card determines which of five possible format bands will apply to it. The information band stores the contents of a given card after it has been edited by means of a format band. Cards are read in automatically after an internal signal signifying a transfer from the associated buffer drum. The Datatron calls for transfers from buffer drums under program control. Certain cards can be passed through a card reader without any reading action.

The transfer of format bands from Datatron storage to the selected Cardatron unit can be done in a preliminary operation, or in the course of data processing. Hence, there is flexibility for handling a variety of cards in a single processing pass up to the storage capacity limits. Selection of format bands is provided for in the plugboard wiring of the punched-card equipment. Once a format band is selected it cannot be changed until a buffer transfer occurs.

During card-reading time the signals actuated by the punched holes are read, 80 columns in parallel, one row at a time, until all 12 rows of the card have been read. A 1-by-80 magnetic shift register is used to transfer the card readings, under control of a format band, to the information band of the buffer drum. Under Datatron program control, the buffer drum unloads serially through the *D* register, which shifts right up to 11 digits and then transfers to drum storage. Certain modifications can be effected through the sign column.

A 20-word transfer to main storage can be done in 11.5 millisec. It may be more desirable to load a quick-access loop and then transfer to main storage by means of block transfer. In transferring format bands to the buffer drum, there is considerable difference between direct transfer and transfer from a high-speed loop. Since 29 words are always involved, the time for a transfer from a quick-access loop will be 89.5 millisec, plus block transfer time for 29 words (or 11.5 millisec x 2), whereas the time for a transfer direct will require 519.5 millisec.

Output operations from Datatron to a Cardatron unit proceed in much the same fashion, but in reverse and through the *A* register. Two Cardatron output units are available, one with an 80-column magnetic shift register, the other (for line printers) with a 120-column register. The 80-column unit also can be used for output printers but this would cut Datatron's printing capability to 80 characters per line.

In other systems (particularly IBM and UNIVAC) using six-bit character coding to provide alphabetic representation, the problem of card input becomes less one of coding and more one of editing. Card readers currently in use in both the IBM 705 and UNIVAC I systems provide for reading rates of up to 240-250 cards per minute. This can be made available in the Datatron through the use of the Cardatron and an IBM 089 Collator (which has a maximum speed of 240 cards per minute in a single feed). Higher speeds exist in RCA BIZMAC, which converts cards to tape at the rate of 400 cards per minute. The NCR 304 will be provided with reading speed of 1,000 cards per minute. Fast input/output units, such as magnetic tapes, are not provided with individual buffering, since the speed-matching problem is not so great, and there is less need to provide time sharing with multiple units.

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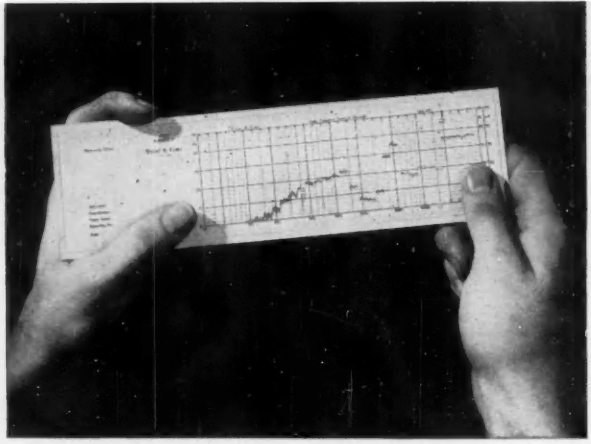

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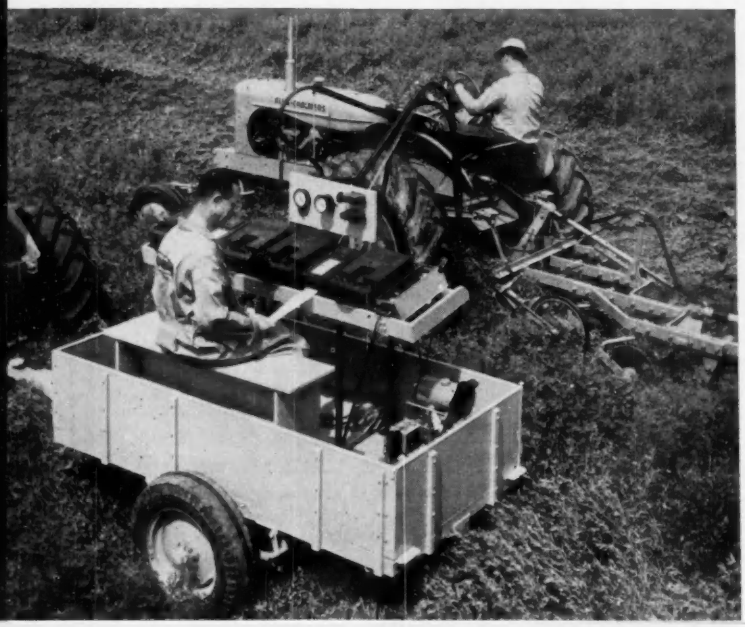

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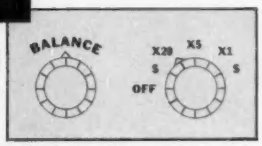

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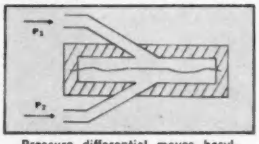

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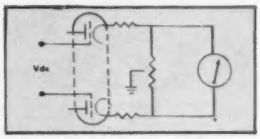
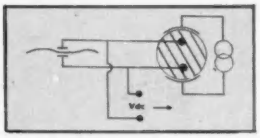


Output applied to cathode follower to drive meter.



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Use Relays for Power Amplifiers

The switch or relay is the ultimate-in-simplicity power amplifier. Adding to it a simple feedback loop and a low-pass filter produces an amplifier with linear response over a wide range of input amplitudes, up to the break frequency of the low-pass filter.

JOHN E. GIBSON and FRANZ B. TUTEUR,
Yale University

The basic circuit for a relay amplifier is shown in Figure 1. The polarized relay closes to one contact for a positive input voltage and to a second contact for a negative input voltage. A deadband or region in which neither contact is closed is typical; usually, then, the relay will exhibit hysteresis. That is, a larger value of coil voltage is required to close the relay than is required to hold the relay closed. Additional gain may be placed between the subtraction point and the low-pass filter to reduce the effect of the hysteresis and deadband. The role of the filter will be explained below.

Assume that a step input is applied at time t_0. Before t_0 the relay was open and there was no charge on the capacitor. The input voltage begins to charge the capacitor, and (as shown in Figure 2) at t_1 the voltage e_r closes the relay, and the output e_m suddenly jumps from 0 to E_b. Because the feedback is negative, the capacitor must now begin to charge to $e_{in} - E_b$ and a downward exponential begins. At t_2 the capacitor voltage has become so small that the relay cannot hold and the contact falls open. The capacitor again begins to charge to e_{in} and the process continues.

Output of the relay amplifier is thus a chain of pulses. This is certainly not a faithful reproduction of the input voltage wave. However, if the load acts like a low-pass filter (as a dc motor will) and is insensitive to frequencies as high as the pulse repetition rate, the amplifier is satisfactory and, in fact, is "linear" over most of the amplitude operation range. If the input signal amplitude is large, the pulses are long and the average value of the output is high. The upper limit on input signal amplitude is reached when the relay remains closed continuously. This limit is determined by the value of the supply voltages on the relay contacts. The lower limit on signal amplitude is determined by the value of the relay deadband.

The amplifier is stable, as has been shown by an analysis using Kochenburger's describing function technique[1], assuming only that the time constant of the low-pass filter is large with respect to any other lag in the loop (such as the time required for the relay contacts to close after a voltage is applied to the relay coil).

Static characteristics

The output of a relay amplifier with feedback is a series of pulses, positive or negative, of amplitude E_b and with length and repetition rate determined by the input. Usually, however, the relay amplifier is employed in an application where only the average value of this train of pulses is important. The output wave shape is completely independent of the load and nowhere in the following analysis need the load be specified.

To determine the static relation between the input voltage e_r and the average output voltage E_m, assume that $e_r = 0$ at t_0, Figure 1. Thus the relay is open and $e_m = 0$. Let a step of voltage, E_r in magnitude, be applied as shown in Figure 2. Then

$$e_r = E_r (1 - \epsilon^{-t/T}) \qquad (1)$$

where $T = RC$. When e_r reaches e_2, the relay closes. Substituting e_2 for e_r in Equation 1 and solving for t_1, the time of closing,

$$\epsilon^{-t_1/T} = \frac{E_r - e_2}{E_r} \qquad (2)$$

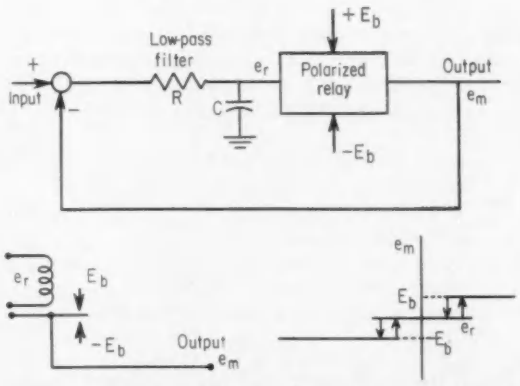


FIG. 1. Basic circuit of a relay amplifier. Also, a polarized relay and a typical static characteristic for it.

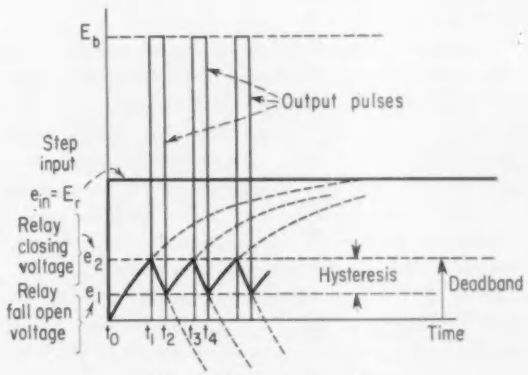
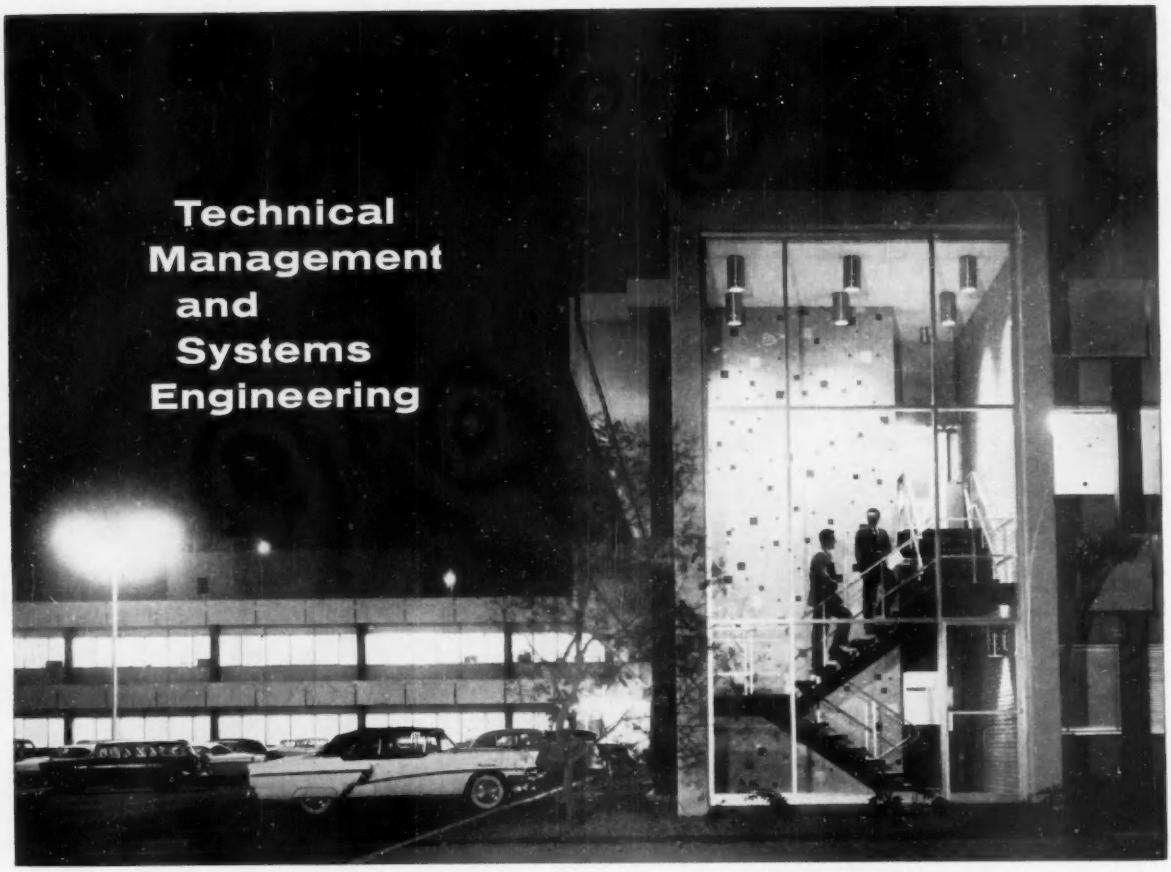


FIG. 2. Voltage wave shapes in response to a step function.



In systems engineering work, it is necessary to bring together a team that includes scientists and engineers of a wide range of technical specialties. In major weapons-systems projects, such teams will include hundreds of scientists and engineers.

But the assembly of a large group of scientists and engineers, no matter how capable they may be individually, does not of itself ensure good systems-engineering performance. The caliber of the project management has a major effect upon its technical accomplishment. It is not easy to coordinate the activities of large numbers of scientists and engineers so as not to stifle their creativeness on the one hand, nor to permit the various development sub-efforts to head toward mutually incompatible objectives on the other.

Of primary importance for good systems management is the philosophy underlying the selection of the supervisory personnel. The head of a technical activity should, first of all, be a competent scientist or engineer. A common mistake – nearly always fatal in systems work – is to fill such positions by non-technical men who have been trained only in management techniques. In the highly complex activities of major systems work, what is required is *technical management*, and of the two words, the word *technical* must never be overlooked.

In the selection of scientists and engineers for technical management, it is essential that the men chosen be broad in their training and approach. Each principal department head, for example, must have a good basic understanding of the technical facts of life of the other departments. When these people get together they need to speak a common language and understand each other's fields, so that proper decisions can be made on the many interrelated problems that come up. The higher the organizational responsibility of a technical manager, the more important this factor becomes.

The Ramo-Wooldridge Corporation is engaged almost entirely in systems work. Because of this, the company has assigned to scientists and engineers more dominant roles in the management and control of the business than is customary or necessary in most industrial organizations.

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or

$$t_1 = -T \ln (1 - e_2/E_r) \quad (3)$$

After the relay closes,

$$e_r = E_r [1 - \epsilon^{-(t-t_1)/T}] \quad (4)$$
$$- E_b [1 - \epsilon^{-(t-t_1)/T}] + e_2 \epsilon^{-(t-t_1)/T}$$

When e_r reaches e_1, the relay opens. The time of opening, t_2, may be found by setting $e_r = e_1$ and solving for $t = t_2$:

$$\epsilon^{-(t_2-t_1)/T} = \frac{e_1 - E_r + E_b}{e_2 - E_R + E_b} \quad (5)$$

thus

$$t_2 - t_1 = -T \ln \left[\frac{e_1 - E_r + E_b}{e_2 - E_r + E_b} \right] \quad (6)$$

With the relay open,

$$e_r = E_r (1 - \epsilon^{-(t-t_2)/T}) + e_1 \epsilon^{-(t-t_2)/T} \quad (7)$$

Note that Equation 7 is Equation 1 plus the term due to the initial voltage on the capacitor. All of the segments of the voltage curve will be exactly the same as those described by Equations 4 and 7. Equation 1 is a special case: there is no charge on the capacitor. The relay closes again at t_3 when $e_r = e_2$ given by

$$t_3 - t_2 = -T \ln \left(\frac{e_2 - E_r}{e_1 - E_r} \right) \quad (8)$$

During the period of time $(t_3 - t_2)$ the output voltage is zero, and during the period $(t_2 - t_1)$ the output is E_b. These two lengths of time represent the cycle of the output voltage wave. The average output is therefore

$$\bar{e}_m = \frac{E_b (t_2 - t_1)}{(t_3 - t_1)} \quad (9)$$

Now, substituting in Equation 6 and Equation 8, we obtain

$$\bar{e}_m = \frac{E_b \ln \left[\dfrac{1 - \dfrac{e_1}{E_r - E_b}}{1 - \dfrac{e_2}{E_r - E_b}} \right]}{\ln \left[\dfrac{1 - \dfrac{E_b}{E_r - e_1}}{1 - \dfrac{E_b}{E_r - e_2}} \right]} \quad (10)$$

This relation gives the negative real result that is required only in the region, $e_2 \leqq E_r \leqq E_b + e_1$. For $E_r < e_2$ the relay does not close: the output is zero. For $E_r < E_b + e_1$, the relay remains closed and the output is E_b. It may be shown that if e_1 and e_2 are small with respect to the battery voltage, the slope of e_m vs. E_r is essentially constant over the operating range. The exact relation between input voltage magnitude and the average of the output voltage may be determined from Equation 10. Figure 3 shows $\bar{e}_m$ vs. E_r normalized to E_b. If the subtractor is not perfect, a somewhat more complex analysis is necessary. It is possible, for example, to derive

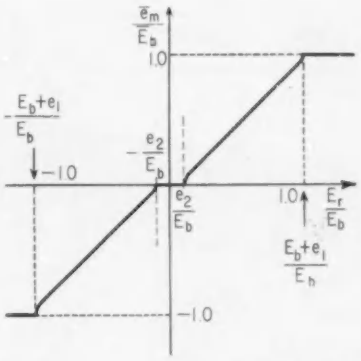

FIG. 3. Static input-output characteristic of a relay amplifier. Compare with characteristic of relay alone in Figure 1.

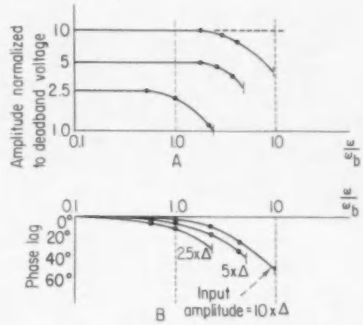

FIG. 4. Amplitude and phase response of relay and amplifier vs. angular frequency normalized to break frequency of filter.

the equivalent of Equation 10 for the case of unequal time constants with the relay open and closed, and also with a resistor adding circuit rather than a high impedance adder[3].

Frequency response

The frequency response of a relay amplifier with feedback is limited (to a first approximation) by the time constant T of the filter, or the "chatter" rate of the output pulses. Actually, however, this chatter rate or output pulse repetition rate depends on the input signal magnitude—where E_r is either greater than E_b or zero, the relay remains always closed or always open. Since the relay amplifier is a nonlinear device, the entire concept of frequency response is contrived, and a measure for one type of input signal will not hold for another. For a step-function input, the relay amplifier is particularly fast and essentially establishes the required average value of e_m in one opening and closing.

The response of a relay amplifier to sinusoidal signals depends on the amplitude and the frequency of the input signal. For signals whose peak amplitude at the input of the relay is less than the value required to close the relay, there is no output. For instance, if the closing voltage of the relay is 10 volts, a signal whose peak amplitude is less than 10 volts will not close the relay. Since the low-pass filter attenuates the amplitude of the input signal, the peak amplitude must be computed at the input to the relay. At the break frequency of the filter, for instance, the filter reduces the input amplitude by a factor of 0.707; thus the minimum input signal amplitude must be 14.14 volts peak. Essentially a relay amplifier will operate properly for normal amplitude signals up to the break frequency of the low-pass filter.

Figure 4 shows the amplitude reduction and phase shift vs. frequency for a typical relay amplifier. The relay closing voltage is 0.1 of the battery voltage applied to the relay terminals and the relay dropout voltage is 0.05 of E_b. The frequency response shown in Figure 4A was obtained by smoothing the pulse train output to recover the input-signal frequency component. When the input-signal frequency is equal to or greater than the break frequency of the filter, especially at low amplitudes, the number of output pulses per cycle becomes small and even the integrated output becomes rather step-like.

Figure 5 shows the various wave shapes for a particular signal: 5A is the sine wave input to the amplifier; its peak amplitude is 0.5 and its frequency is the break frequency of the low-pass filter. Figure 5B is the wave-

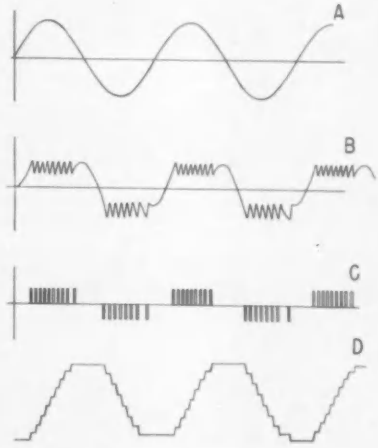

FIG. 5. Voltage response to sinusoidal driving signal. A—sinsoidal input signal at break frequency (ω_b) of low-pass filter; B—output of low pass filter; C—output of relay amplifier; D—integrated output of relay amplifier.

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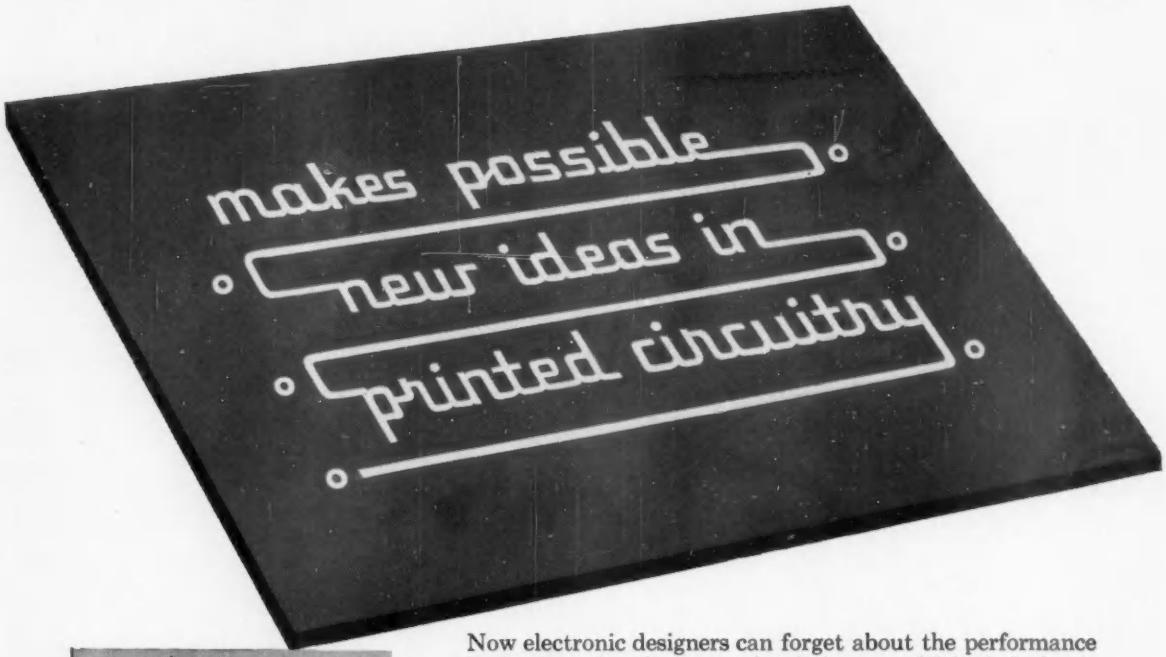

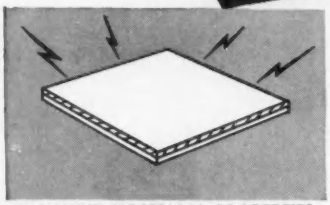

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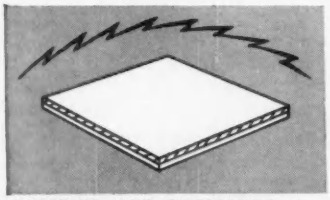

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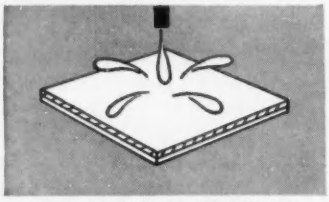

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form at the output of the low-pass filter and illustrates the deadband hysteresis of the relay. Figure 5C is the output of the relay and 5D is the integrated output. Figure 5D reveals a rather good sine shape even though the input is close to the upper frequency limit of operation.

A practical example of a relay amplifier used to drive the actuating motors of an automatic field plotter[2] is shown in Figure 6. Here separate amplifiers drive the two relay coils required to complete the motor contacts.

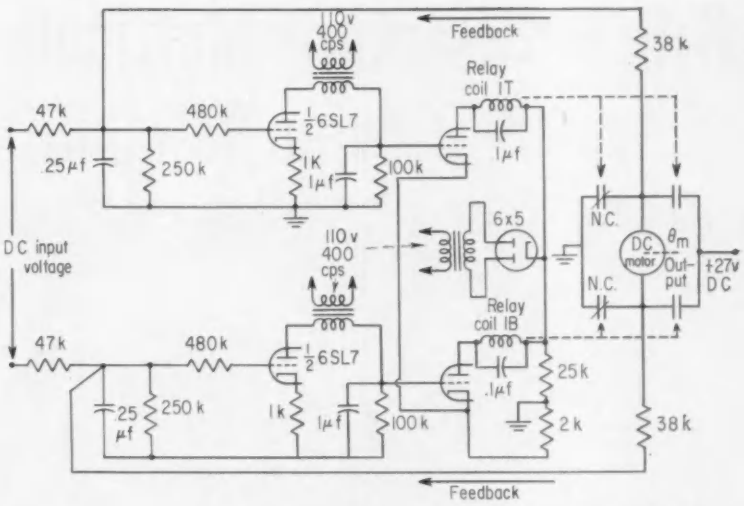

FIG. 6. A practical example of a relay amplifier used to drive the positioning motor of an automatic plotter.

It is difficult to establish an equivalent loop gain constant for the relay amplifier with feedback without making several rather arbitrary assumptions. However from Figure 4 it can be seen that such an equivalent gain depends on the input signal amplitude. At maximum amplitude signal the break frequency of the closed-loop response of the experimental amplifier occurs at about $4/T$ and for minimum amplitude signals the break approaches $1/T$. This would indicate a loop gain constant of about 3 at maximum signal amplitude and zero for minimum amplitude signals.

The amount of phase shift contributed by the filter to the overall phase shift shown in Figure 4B is inversely related to the gain of the amplifier, due to the negative feedback. In addition to decreasing the closed-loop phase shift, an increase in amplifier gain will act to reduce the effective deadband, thus increasing the usefulness of the amplifier at low signal amplitudes. As the gain is increased, the loop becomes less stable due to the increased effect of previously neglected lags in the amplifier and relay itself, until finally the amplifier goes into stable oscillation; that is, its output for no input is a continuous string of alternate positive and negative pulses of a predictable frequency. As a signal is placed on the input terminals, the length of the positive pulses grows longer and the negative pulses shorter or vice versa; thus the averaged output follows the input. This type of operation is more sensitive to low-amplitude signals than stable operation and will have minimum phase shift from input to output. However, the continuous vibration of the power element under quiescent conditions may be undesirable.

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1. *THE RESPONSE OF RELAY AMPLIFIERS WITH FEEDBACK*, J. E. Gibson, F. B. Tuteur, "Trans. AIEE", Vol. 76, Part II, 1957.
2. *AN AUTOMATIC FIELD PLOTTER*, Gelfand, Shinn, Tuteur, "Trans. AIEE", Vol. 74, Part I, 1955, p. 73.

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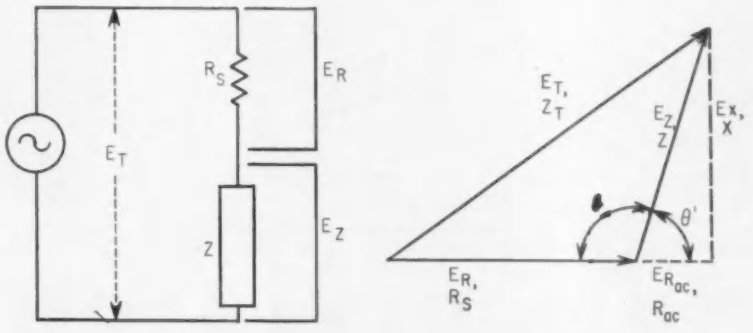

FIG. 1. Schematic and vector diagrams for three-voltmeter method of determining impedances and phase angle.

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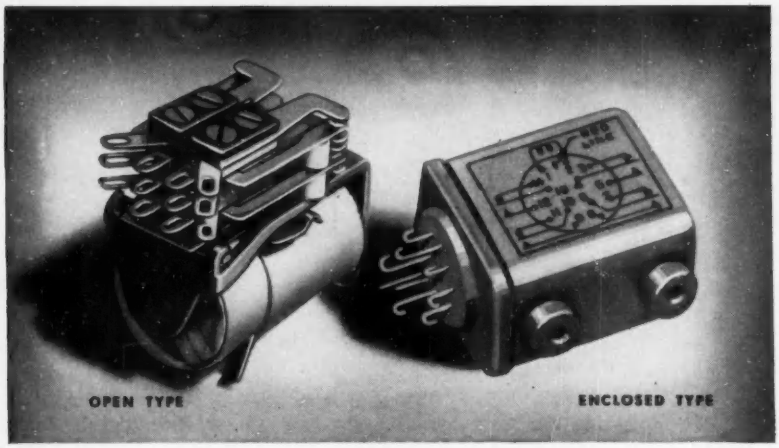

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Open	Maximum Coil Resistance (OHMS)	Minimum Power Requirements Per pole at 25° C (WATTS)	Maximum Contact Form With rated current at 32 V.D.C. or 115 V.A.C. (non-inductive load)	Maximum Coil Watts	Enclosed
SM	9,000	.2	4 PDT 5 Amps. or 3 Amps. 6 PST 3 Amps.	3.75	HSM
SMD-2	9,000	1.0	SPNO Parallel Contacts Make 80 Amps. Break 20 Amps. at 32 V.D.C.	3.75	HSMD-2
SC	18,500	.16	4 PDT 5 Amps. or 3 Amps. 6 PST 3 Amps.	4.5	HPSC
SA	18,500	.14	4 PDT 5 Amps. or 3 Amps. 6 PST 3 Amps.	4.5	HLSA
SM-RF	9,000	.2	SPNO, SPDT, DPNC, SPNC, DPNO	3.75	HSM-RF HLSM-RF
SAD-2	18,500	1.0	SPNO Parallel Contacts. Make 80 Amps. Break 20 Amps. at 32 V.D.C.	4.5	HLSAD-2

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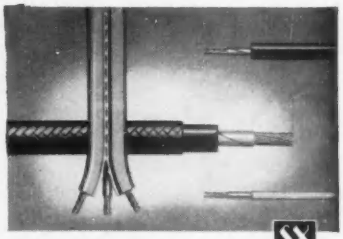

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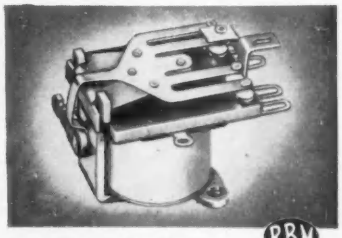

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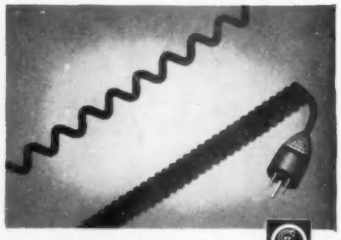

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od"[1,2,3], determine the phase shift, and the inductive and resistive components of a transducer coil over specified ranges of frequency, amplitude, and loading. And from this data determine how the frequency response of the coil varies with amplitude and loading. Figure 1A presents the basic test setup and Figure 1B the voltage and impedance diagrams.

Solution 1—by graph

If a voltage, E_T, is applied across an unknown impedance, Z, in series with a known precision resistance, R_s, the voltage relationship is

$$E_T^2 = E_R^2 + E_Z^2 - 2E_R E_Z \cos\theta \quad (1)$$

With $E_R = E_Z = 1$,

$$E_T/E_Z = [2(1+\cos\theta')]^{1/2} \quad (2)$$

and $\cos\theta' = (E_T^2 - 2)/2$

(Reference 3 shows the simplifications.) Figure 2 is a graph constructed to eliminate the trigonometric calculations involved. To use the graph, adjust R_s until the voltage drop across it equals the voltage across Z, then connect a high-input impedance meter across both and measure E_T. Take the ratio E_T/E_Z, and find its location along the rim of the graph. From it, drop a perpendicular to the horizontal axis to find $\cos\theta'$ and read $\sin\theta'$ from the vertical axis.

Z is known because E_Z was set equal to E_R, the drop across R_S, and R_S is a precision decade resistor or a calibrated multiple-turn potentiometer. One can now calculate a large number of parameters:

$$I = E_Z/Z$$
$$Q = \tan\theta'$$
$$\text{Core loss} = E^2/Z\cos\theta'$$

When R_{ac} and x are in series,

$$R_{ac} = Z\cos\theta'$$
$$X = Z\sin\theta'$$

and in parallel,

$$R_{ac} = Z/\cos\theta'$$
$$X = Z/\sin\theta'$$

Solution 2—by special instrument

For θ' between 0 and 90 deg, E_Z/E_T is between $\frac{1}{2}$ and $1/\sqrt{2}$. If, as in Figure 3, there is a network across the source and in parallel with E_T, and if the variable resistor takes up from $\frac{1}{2}$ to $1/\sqrt{2}$ of the total resistance of the network, the voltage equal to E_Z will exist for some setting of a variable resistor in the network. For greater sensitivity, the total resistor variation $(1/\sqrt{2}) - \frac{1}{2} = 0.2071$ is assigned to a decade or a precision potentiometer. Then $E_Z/E_T = (N/K) + \frac{1}{2}$, where N is the dial indication between zero and maximum, and

$$K = \frac{\text{maximum indication}}{0.2701}$$

Substituting for E_Z/E_T in Equation 2,

$$\cos\theta' = \frac{\left(\frac{K}{N+0.5\ K}\right)^2 - 2}{2}$$

which will give values of the cosine of the phase angle in terms of the precision potentiometer readings.

Figure 4 is a schematic of the completed instrument. Actual design will differ according to the ranges needed. Since the input transformer secondary impedance presents a lower limit to the measured impedances, it and the value of the decade resistor should be chosen accordingly. The network in parallel with the ac source can be anything as long as the ratios are adjusted correctly and the meter used for measuring does not load the portion between wiper and low side, i.e., as long as this resistance is smaller than 1/100 of the meter input impedance. This is also required of the impedance under test.

Operational instructions

After Z is connected and voltage applied, switch voltmeter alternately between R and Z positions and adjust R and source voltage until both voltages are equal and have the required amplitude. Then switch to T and adjust potentiometer until voltage equals previous readings. Convert potentiometer dial indication into values of phase angle and/or sine and cosine values of that phase angle.

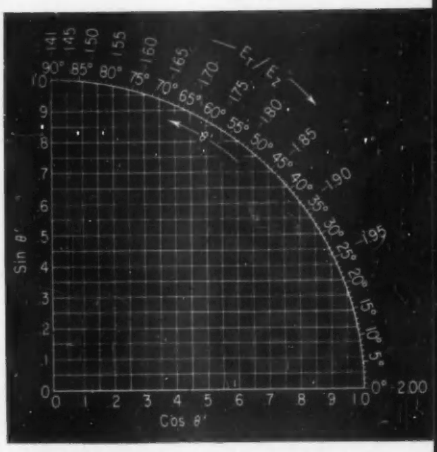

FIG. 2. Enter this graph with E_T/E_Z known and read off phase angle, θ', and the sine and cosine of the phase angle for calculating the resistive and inductive components.

Simple as it is, this instrument is accurate. It gets away from the inaccuracies of the mathematical solution[2] of the three-voltmeter method caused by the necessary approximations. It gets away from the inaccuracies of the purely graphical solution[3], which, even if the meter inaccuracies are discounted, requires care in draftmanship and remeasuring of lines and angles. Finally, it totally gets away from meter inaccuracies—the meter is used for all three readings at one point only. Accuracy is limited only by wave-form distortion and by the accuracy of the resistors used, and this accuracy at the present state of the art is quite high.

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2. *USE LESS GRAPH PAPER*, H. Havicek Jr., "Control Engineering", February 1957, p. 16.
3. *STILL MORE ON SHEPARD ARTICLE*, G. J. Hegedus, "Control Engineering", May 1957, p. 12.

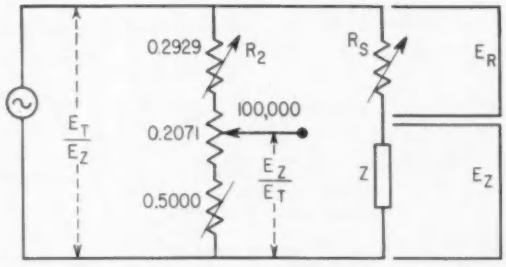


FIG. 3. Circuit diagram of instrument for direct measurement of the cosine of the phase angle.

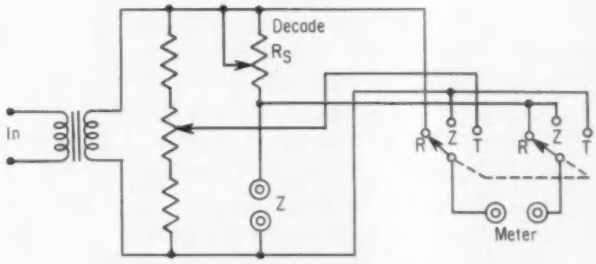
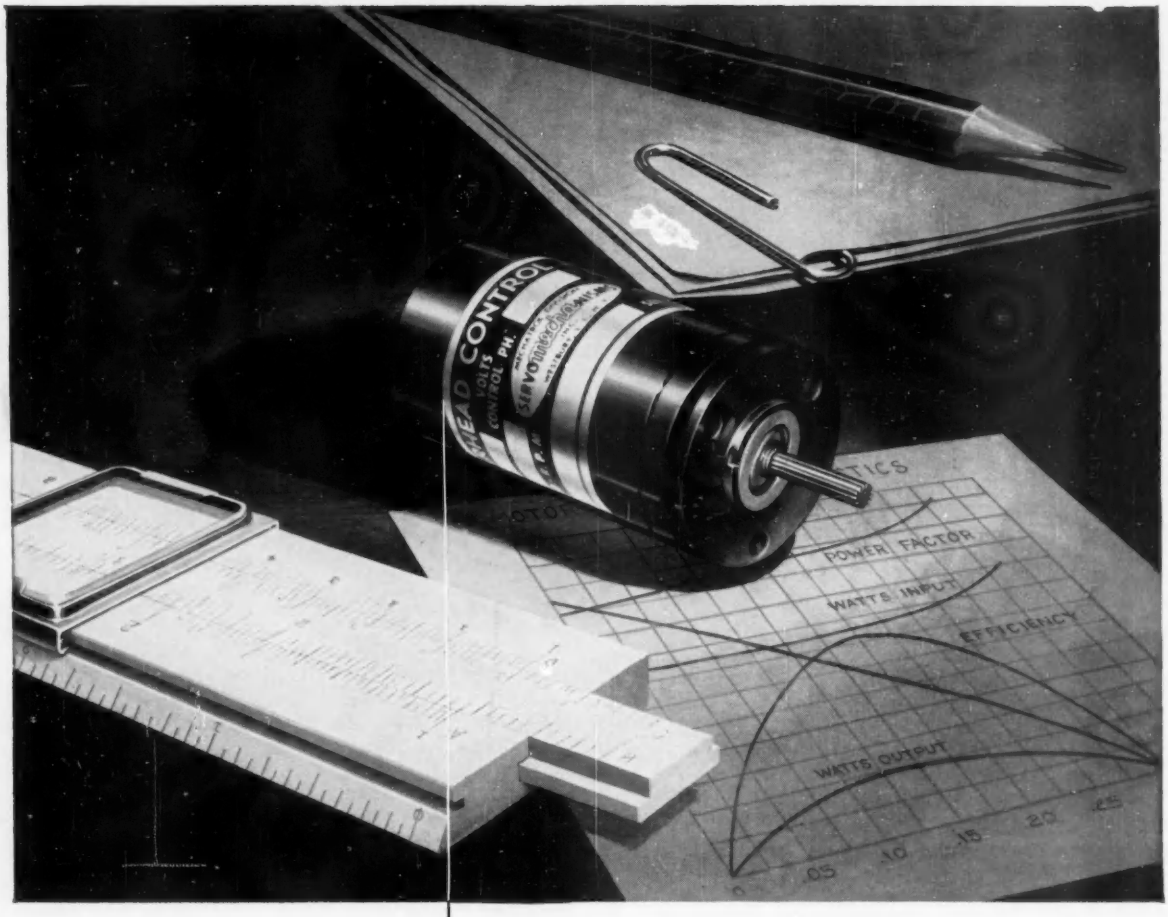


FIG. 4. Schematic of test instrument. Accuracy limited only by wave distortion in inductive circuit tested.



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$$G(j\omega) = \frac{K(1+j\omega a_1)\ \ldots\ (1+j\omega b_1+(j\omega)^2 c_1)\ \cdot\ \cdot\ \cdot}{(j\omega)^p\ \ (1+j\omega\tau_1)\cdot(1+j\omega d_1+(j\omega)^2 f_1)\ \ \ldots\ \cdot\ \cdot\ \cdot} \qquad (1)$$

For design work the corresponding frequency characteristic must be calculated, and for a reasonably accurate quantitative result the amplitude and phase characteristics must be constructed; this can be done quite easily using logarithmic coordinate systems and templates.

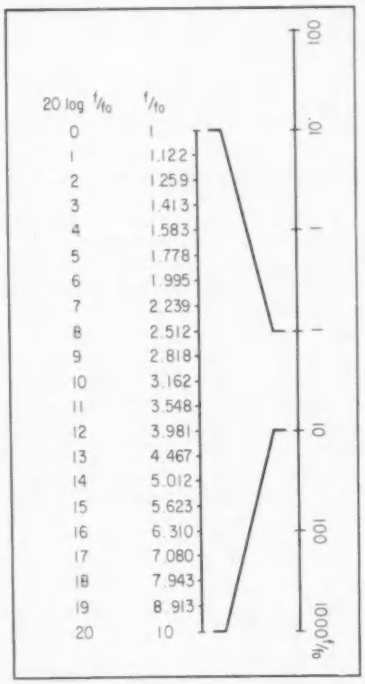


FIG. 1. The frequency range used. For one decade the 19 intermediate points are shown.

Now, the use of templates has some drawbacks due to its analog nature:

- The templates must be made for one specific coordinate system, the units of which cannot be chosen for the particular problem at hand.
- The templates and the graph paper may not "age" in the same way—and not all graph papers really hold the unit lengths exactly.

For more involved operators with five, 10, or even more factors, all one's attention is required to draw all the curves correctly and add them correctly with the right sign. It is not easy to instruct a typist to do it and be sure of the result.

A way of carrying out these calculations digitally is based on the same principle. It involves calculation of 20 log $G(j\omega)$ and the phase for the standard factors of Equation 1 for a frequency range of 1,000:1 on both sides of the break frequency and for 20 logarithmic equally-spaced frequencies per decade (see Figure 1).

For each factor the amplitude values in tabular form are written on a paper strip which is glued to one side of a wooden stick. On the opposite side of the stick the phase values are placed correspondingly.

In this way 10 sticks are made for a first-order factor in the numerator, 10 sticks for a first-order factor in the denominator, and 19 sticks for a second-order factor in the denominator with the damping factors equal to 1.00, 0.95, 0.90 . . . . , 0.10. In addition, there are sticks for $(j\omega)$, $(j\omega)^2$, $1/(j\omega)$, $1/(j\omega)^2$ and $e^{j\omega\tau}$.

For the amplitude values the unit used is "centi-bel" ($\frac{1}{10}$ of a db or 200 log $|G(j\omega)|$), and for the phase values the unit is 1 deg. Positive numbers are written in black and negative numbers are written in red.

To calculate a frequency characteristic, take out a number of sticks, one for each factor, place them along a frequency axis just like a template (see Figure 2) and squeeze them together. This takes only a few minutes. Performing the calculation simply means adding the numbers from all the sticks together for each frequency over the frequency band of interest; one side gives the values for the amplitude, the other side the phase values. This is done in a few minutes with an adding machine and perhaps even more quickly by a typist without much instruction.

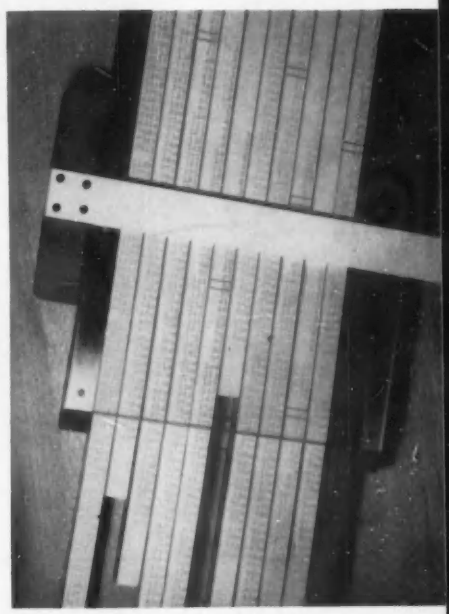
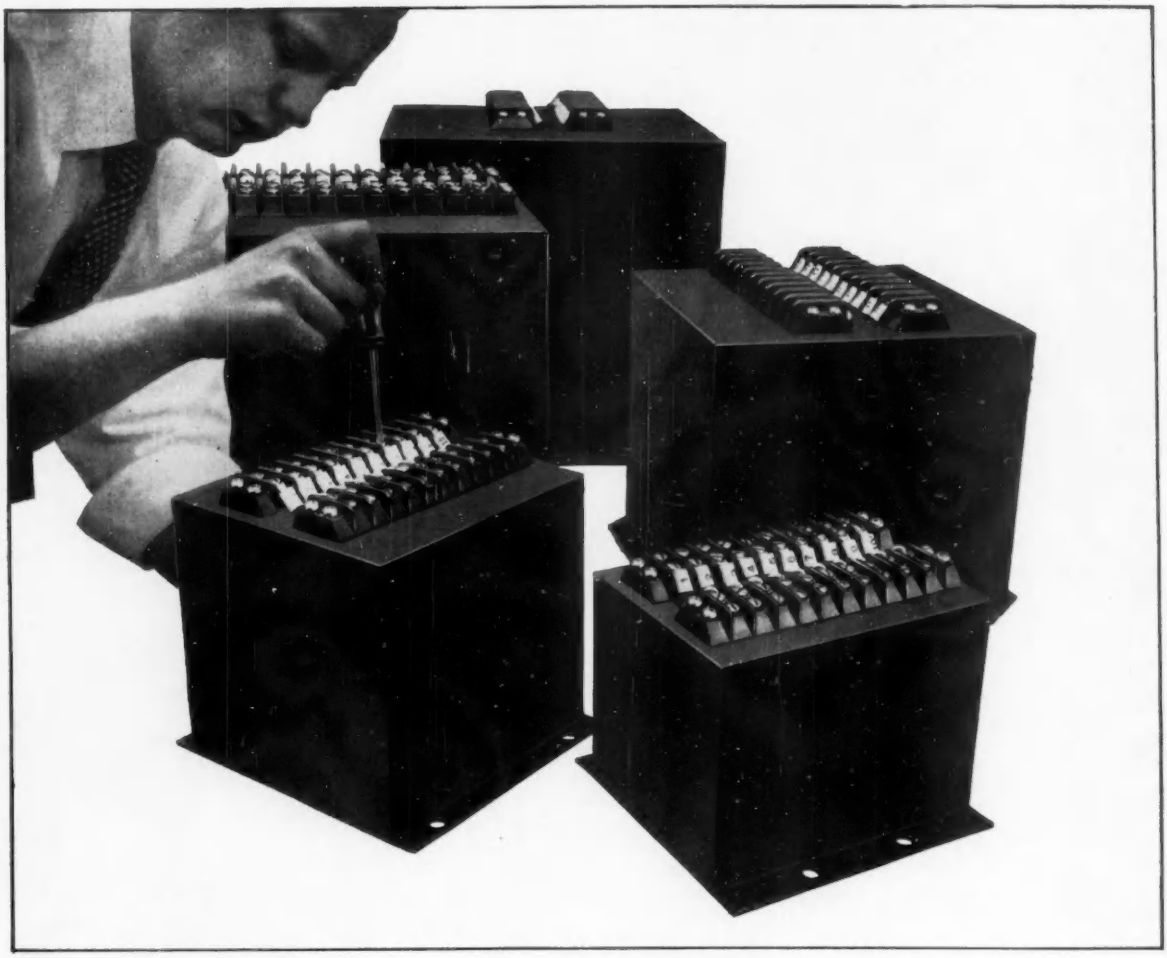


FIG. 2. The digital slide-rule uses a stick for each factor in transfer function.

The paper strip from the adding machine contains the amplitude and phase values and a curve can be drawn in whatever coordinate system is desired.

Because the units used are $\frac{1}{10}$ db and 1 deg, respectively, the calculated amplitude and phase values for an operator with 10 factors may be $\frac{1}{2}$ db and 5 deg in error for a single frequency. This results in some spreading of the points, but the curve drawn is much more accurate and always good enough for engineering work.



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Servos Shake the B-58

W. R. NASS, Convair (San Diego)

During flight test an airplane is in constant danger of flutter-induced destructive vibration. At low speeds the vibrations are prevented from becoming destructive by structural and aerodynamic damping, but at high speeds they may shake the plane to pieces.

A wing and tail vibrator system was designed for the new supersonic B-58 Convair "Hustler" to explore the flutter vibration characteristics at relatively low speeds and safe flight conditions. At each of several safe flight speeds the structure is vibrated at selected resonant frequencies and the stimulation stopped suddenly. For each test the time required for the vibration to decay to a given value is noted and the value of the damping calculated. The data is plotted and extrapolated. As shown in the example in Figure 1, the speed at which the vibration may not decay, but may become dangerous, is predictable.

Vibration system

Two methods of stimulating the aircraft structure are employed. For frequencies below 5.0 cps the aircraft controls are vibrated through the auto-pilot. At higher frequencies, electrohydraulic vibrators are used.

The vibration frequency of the system is adjustable from 1.5 to 50.0 cps. The vibrators are not used below 5.0 cps because of very low force output. Instead, the control signals excite the autopilot and vibrate the aircraft by means of aerodynamic forces. Above 5.0 cps, the control signals operate the wing or tail vibrators. The vibration frequency may be set manually to any value. When searching for resonances the vibration frequency may be varied through its entire range, either manually or automatically. A "quick-stop" feature stops the vibrators suddenly and permits observation of vibration decay rates.

The system is operated from a control unit which includes provisions for starting and stopping the system, selection of vibration to either the wings or the tail, a choice of automatic or manual frequency sweep, a choice of symmetrical or asymmetrical vibration of the wings, and a choice of energizing the aircraft autopilot for low frequency vibration, or the vibrators at the higher frequencies.

Three control servo amplifiers receive ac input signals from a frequency generator and convert them to push-pull dc to drive the hydraulic servo valves of the related vibrators. Differential transformers feed back the vibrator positions as ac signals for direct comparison with the input.

The hydraulic supply is an electric-motor-operated high-pressure oil pump and reservoir that furnishes energy for the vibrators. Vibration frequency is selected by a dial marked with two scales: 1.5 to 15.0 cps and 5.0 to 50.0 cps. Because of the narrow range of each scale (10:1) a velocity servo is used as the basic frequency generating method. A logarithmic potentiometer driven by the dial furnishes a 400-cps signal to the velocity servo system. Servomotor speed is directly related to the dial position. The vibration frequencies are generated by synchros geared to the servomotor. The output signals from the synchros are modified by a force-control potentiometer also operated by the frequency-control dial to increase the force output of the vibrator linearly from about 25 lb at 5 cps to 150 lb at 40 cps.

Vibrators

Each vibrator, Figure 2, is 4.5 in. sq and 8.5 in. long and weighs about 25 lb. The moving mass is a 16-lb weight of machineable tungsten alloy

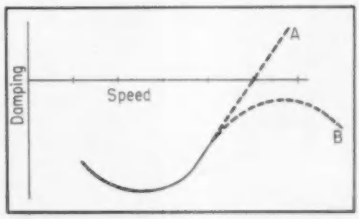

FIG. 1. Aircraft speed vs. vibration damping for a hypothetical wing. Curve A is dangerous. Curve B is acceptable.

(Mallory 1000 Metal) attached directly to a double-ended piston. The piston drives the weight in translational motion. The maximum amplitude of motion is limited to 0.87 in.

Hydraulic fluid flow to the cylinders is regulated by a pressure-control servo valve located entirely within the main body of the vibrator. The maximum oil demand of a vibrator is less than 1 gal/min. The operating pressure may be as high as 3,000 psi.

The force generated by the vibrator is the reaction force due to the acceleration and deceleration of the weight. If it is assumed that the motion of the weight is basically harmonic, then the displacement, velocity, and acceleration of the weight can be defined for any frequency. For the B-58 vibrators, the force is equal to 0.81 $f^2 x$ where f is the frequency (cps) and x is the piston double-amplitude in inches.

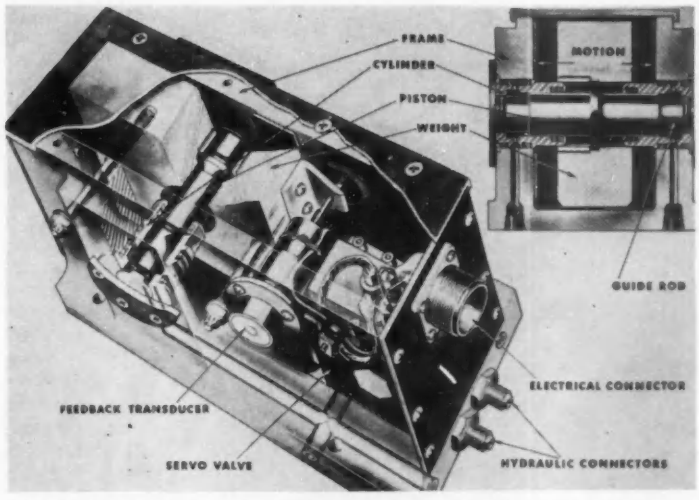

FIG. 2 Electrohydraulic vibrator develops forces as reaction to acceleration of 16-lb weight. Differential transformer provides ac position feedback from vibrator.

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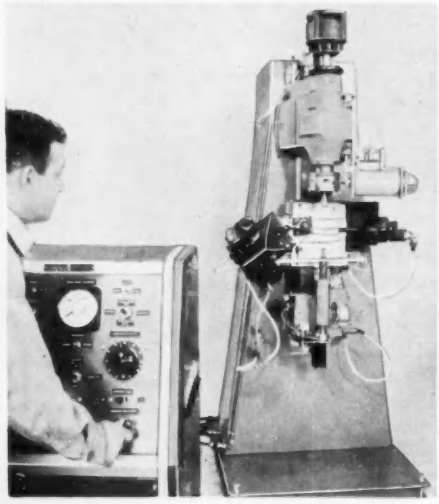
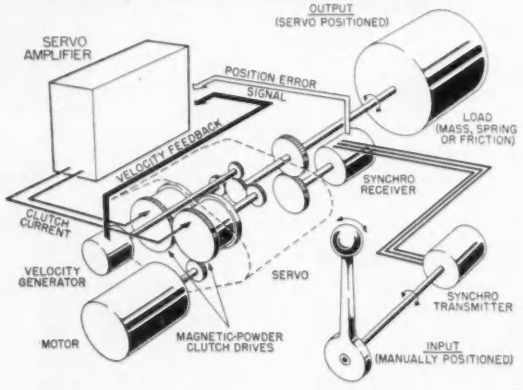




REMOTE POSITIONER protects operator.

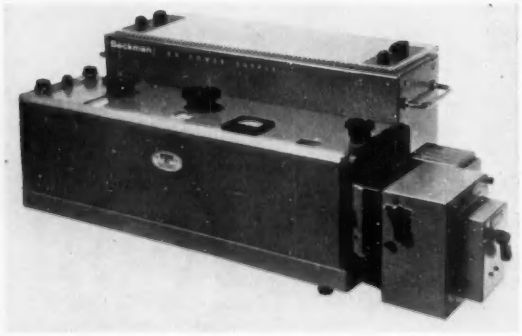
Photo (left) shows a practical application of the Lear Electrolink remote positioning system. The tool being controlled is a modified Hardinge lathe, which precision-machines radioactive materials. Electrolinks are used on both the compound and the cross-feed motions, and on a milling attachment. The entire unit is undergoing tests in a GE laboratory.

The Electrolink itself, as may be seen in the schematic, is a closed-loop servomechanisms with

- a Position Transmitter, which converts manually positioned input into error voltage;
- a Remote Position Control, which detects the error and transmits clutch current to drive the load in the proper direction;
- the Servo Drive, which drives two magnetic-powder clutches in opposite directions through a gear reduction.

The servo causes loads to follow movements of the positioning device at angular velocities up to 500 rpm, and the magnetic-powder clutches provide for quick, positive stops of the load motion. The positioner itself is sensitive within ¼ deg, reaches maximum speed in 1/50 sec, and develops an output torque of 100 lb-in. Oscillation and hunting are eliminated by transmitting a voltage (proportional to servo-drive velocity) from an integral velocity generator to the control. Stability performance and gain may be adjusted to a wide range of loads, including inertia, friction, and light spring types. The entire servomechanism occupies less than 1 cu ft of space, and weighs under 11 lb. Models are available for either 60- or 400-cycle input.—Lear, Inc., Grand Rapids, Mich.

Circle No. 1 on reply card



VERSATILE ANALYZER features flexible design.

This new gas analyzer, Model 7C, measures carbon dioxide, hydrogen, ammonia, and other process stream gases. Various arrangements use standard and specially designed components. Single or multiple ranges are available. With three outputs to choose from, the designer can specify almost any recorder or indicator. Standard output is 0 to 5 mv dc, but the unit can be supplied with an auxiliary amplifier for current output or with an electropneumatic transducer for air output. Standard cases are designed for either flush or surface mounting. An explosion-resistant condulet may be specified.—Arnold O. Beckman, Inc., South Pasadena, Calif.

Circle No. 2 on reply card

PSYCHROMETER needs no calibration.

This rugged, highly sensitive instrument continuously measures percent moisture in all classes of textiles, papers, plastics, tobaccos, etc. Unlike other moisture meters, which are based on a single electrical measurement, the Hunter Electro-Psychrometer measures the product of the influence of three different electrical phenomena: static electricty, electrical resistance, and variation of dielectric constant. In each range of moisture content, one of these electrical phenomena is predominant. The unit operates on the most appropriate one, and, as conditions vary, is corrected by the other two. At the same time it provides visual warning and automatic speed control for varying moisture content.

The unit requires no calibration, zeroing, or resetting for different materials or different thicknesses, and is unaffected by reasonable changes in voltage. Pickups consist of three or more completely adjustable feeler rollers that measure the humidity across the full width of the material to be controlled. Action is taken either on the wettest section or on an average value.—Hunter Controls, Inc., North Adams, Mass.

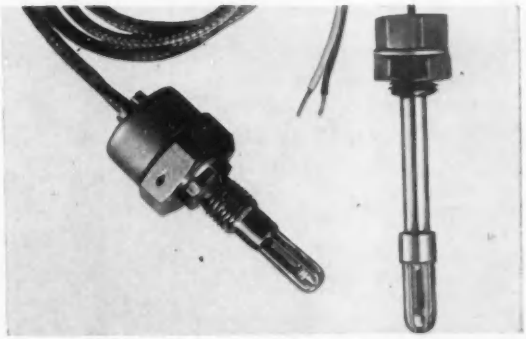
Circle No. 3 on reply card

NEW CONVERTER will multiply and divide.

The Multiverter, shown here, is said to be the first commercial analog-to-digital and digital-to-analog converter that is completely transistorized. More than 15,000 analog to digital conversions per second, and 300,000 digital to analog, at accuracies within 0.01 percent, are claimed. When converting a number n to a voltage, the product nx may be formed simply by supplying the variable voltage x. When converting a voltage a to a digital number, the quotient a/v in digital form may be effected by supplying the voltage v. High-frequency signals can be followed at reduced accuracy.—Packard-Bell Electronics Corp., Los Angeles, Calif.

Circle No. 4 on reply card

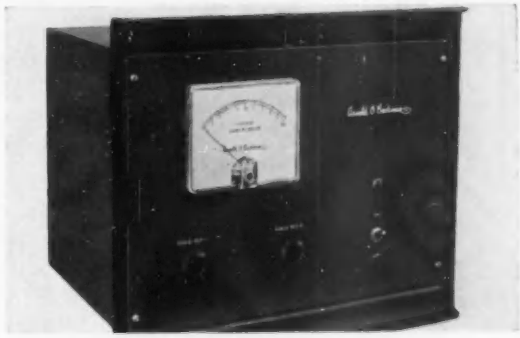
RESISTANCE BULBS have protective cages.



The exposed platinum sensing element of these new resistance thermometers is in almost immediate contact with the environment to be measured. The result is extremely fast thermal response: 2.5 sec in air and 50 millisec in water. Units are accurate to within plus or minus 1.0 percent of full scale over their temperature range of minus 320 to plus 750 deg F, and have a repeatability within 0.2 percent. Resistance windings are supported on mica cards or ceramic insulating posts and completely protected by stainless steel cages. Pickups will withstand pressures to 1,500 psi.—Trans-Sonics, Inc., Burlington, Mass.

Circle No. 5 on reply card

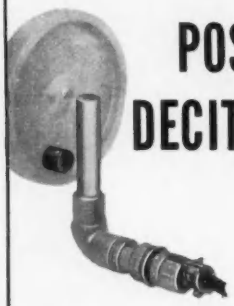
AC POWER SUPPLY eliminates batteries.



The compact unit shown here is a new source of power for the Beckman DU Spectrophotometer, which is now being offered as a line-operated instrument. The new supply not only eliminates the need for the standard storage battery and dry cells, but replaces the original ultraviolet power and the battery box for the DU hydrogen lamp and the DU Photomultiplier accessory. In a continuous 30-hr test with its new equipment, the Spectrophotometer had a zero and full-scale drift of less than 1 percent.—Beckman Instruments, Inc., Fullerton, Calif.

Circle No. 6 on reply card

MODEL MH-2



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FLEXIBLE COUNTER

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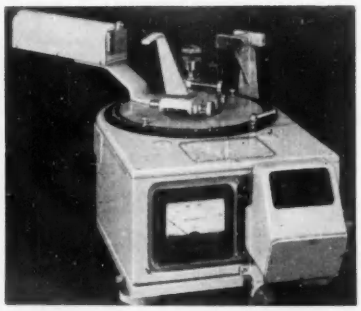

CRYSTAL GONIOMETER

This high-precision quartz crystal x-ray goniometer permits unskilled operators to orient crystal surfaces and lattice planes with a high accuracy (within 30 sec of arc). Other features of this new angle tester: a large direct-reading scale, simple controls, and high sensitivity. It may be used with either a high-intensity microfocus x-ray unit or conventional x-ray diffraction equipment.—Jarrell-Ash Co., Newtonville, Mass.

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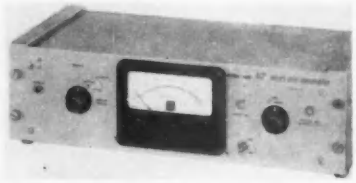

MICRO-MICROAMMETER

The Model 412 Micro-Microammeter features a single 6-in. meter scale covering six decades from 10^{-12} to 10^{-4} amp. Typical uses include reactor-power-level indication and control, aerial and area monitoring, materials testing, and measurements of microcurrents from sources of 1 volt or more. Response time is less than 2 sec to 90 percent of the currents larger than 10^{-12} amp with 5,000 mmf across the input. Zero drift is within 0.5 decade in 8 hrs; accuracy is within 0.2 decade.—Keithley Instruments, Inc., Cleveland, Ohio.

Circle No. 9 on reply card

WAVEFORM ANALYZER

The LF-2 Subsonic Analyzer automatically and permanently records on paper the frequency and amplitude of waveform components. It has a resolution of 0.5 cps over a frequency range of from 0.5 to 2,250 cps, and six different sweepwidths. Applications include vibration and sound analysis, acoustical studies, noise analysis, servo analysis, and general low-frequency waveform investigations. A scan range selector provides sweepwidths of 2 to 500 cps and variable center frequency control. Resolution is adjustable in steps from 0.1 cps to 20 cps.—Panoramic Radio Products, Inc., Mount Vernon, N. Y.

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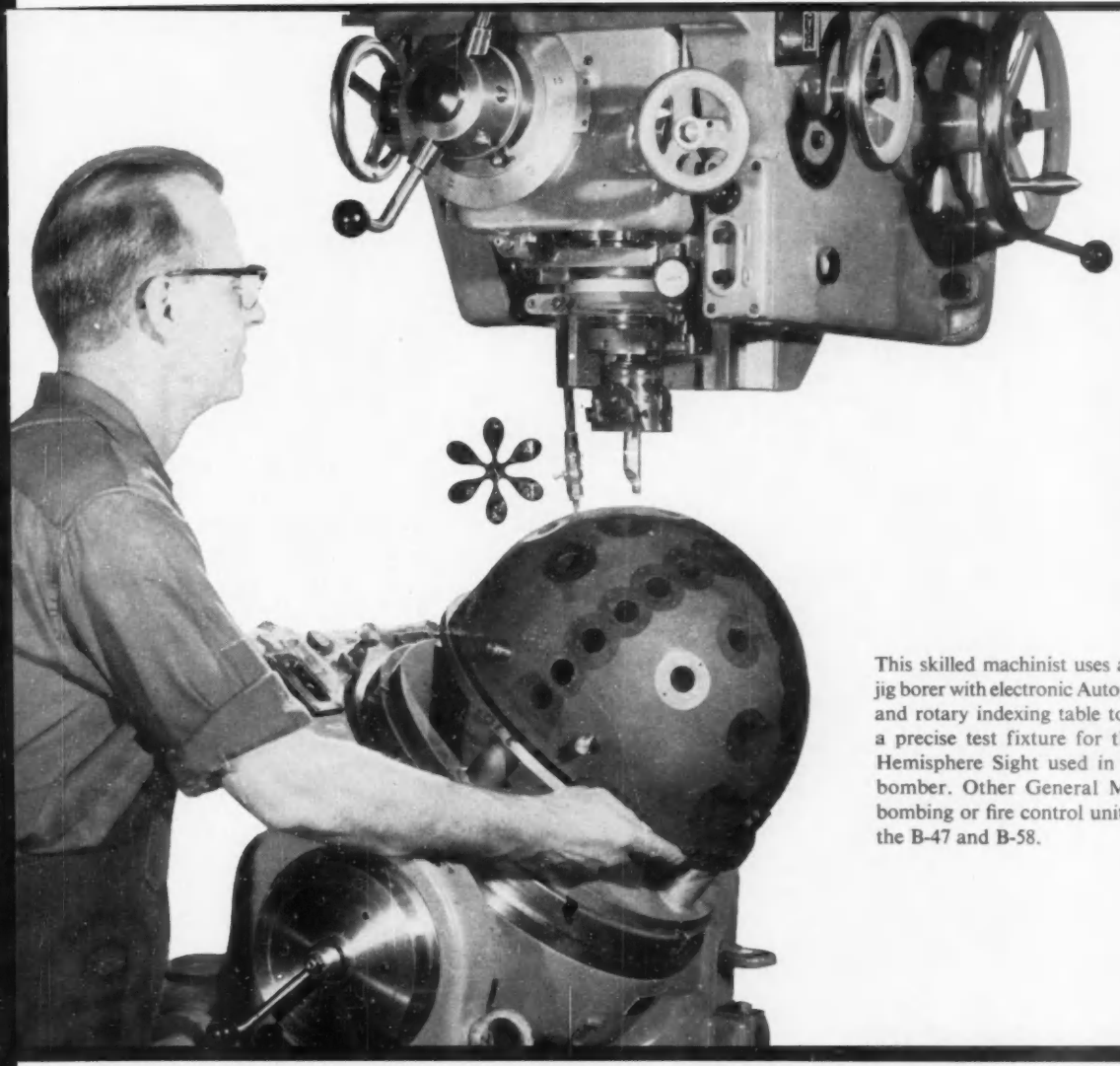


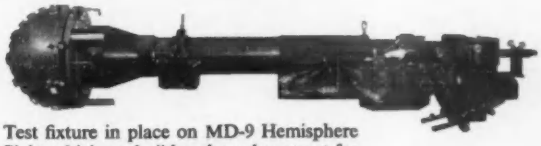
This skilled machinist uses a Lindner jig borer with electronic Autopositioner and rotary indexing table to produce a precise test fixture for the MD-9 Hemisphere Sight used in the B-52 bomber. Other General Mills-built bombing or fire control units fly with the B-47 and B-58.

*B-52 gunners are better marksmen because of this General Mills craftsman

Maintaining accuracy of the MD-9 Hemisphere Sight for the tail defense system in B-52 bombers calls for unusually close tolerances. Holding these tolerances requires exacting test fixtures. We designed, engineered and built many of them.

We'd like to tell you more about how we combine creative engineering and fine precision production to serve industry and military. Our unified team can handle research, development or manufacturing—or the whole package. Send for facts, Dept. CE7

The optical device in the picture has flat, microfinished surfaces with angular accuracy within two minutes of arc surrounding lens openings. The critical flat areas and openings are located from bearing holes that are held within +.0002″, −.0000″



Test fixture in place on MD-9 Hemisphere Sight which we build under subcontract for the Crosley Division of Avco.

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VIBRATION:	**20gs to 2000 cps (3 attitudes)**
POWER:	**2.5 watts at 40°C, 0 watts at 140°C**

* also known as a cricket

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ELECTRONIC GALVANOMETER

The Model 204A electronic galvanometer is a combination dc null detector, linear deflection indicator, microvoltmeter, micro-microammeter, and low-level dc amplifier. Though functionally equivalent to suspension galvanometers, its chopper-stabilized, all-transistor circuit gives it many additional advantages. Insensitive to vibration, shock, microphonics, and stray pickup, it can be mounted in any position, and will withstand severe overloading with no offset on return to zero. Seven decaded ranges cover dc voltages from 10 mv to 10 volts full scale, or currents from 0.001 microamp to 1 milliamp full scale. Input resistance is a constant 10,000 ohms.—Kin Tel, San Diego, Calif.

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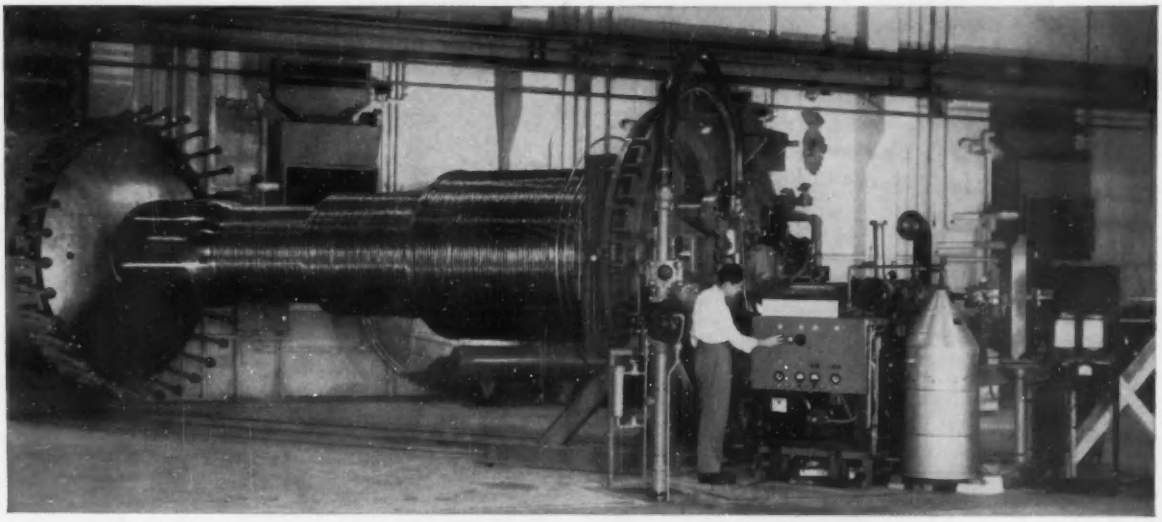
VERSATILE PLOTTER

The Electroplotter S, a new high-speed plotter, accepts punched paper tape, punched cards, or magnetic tape from general-purpose computers. Simplest output of the machine is a two-dimensional *X-Y* point-to-point plot. In more complex displays, digital information is presented at demandable positions over the plotting area; discrete points are plotted at any position, "flagged" by a line of digital and sym-



Van de Graff accelerator in ONR's Naval Research Laboratory. Many substantial contributions in the field of nuclear physics have been made by ONR scientists.

U. S. Navy Photo

OFFICE OF NAVAL RESEARCH BRINGS SCIENCE OF FUTURE TO AMERICA'S SEA ARM

The Office of Naval Research, formed in 1946, has already become an extremely important contributor to the effectiveness of the Navy and a full-fledged member of the scientific community. ONR's mission is "to plan, foster, and encourage scientific research . . . as related to the maintenance of future naval power and the preservation of national security . . ."

The Navy has an enormous requirement for nearly every kind of scientific and technological information. Since its establishment, ONR has supported scientific research in nearly every major scientific field. Its research results support development in Navy bureaus, in aircraft, guided missiles, ships, medicine, training, logistics and other areas. ONR also supports exploratory development to test the feasibility of radically new weapons concepts.

Most ONR research is performed under contract in universities, non-profit institutions, and industrial laboratories. Research is also performed at the four laboratories under ONR supervision: the Naval Research Laboratory, the Training Device Center, the Underwater Sound Reference Laboratory, and the U. S. Naval Biological Laboratory.

Out of ONR's laboratories have come such developments as the earliest radar; major advances in radio telescopy; high altitude research (employing both balloons and rockets, such as the well-known Viking); many contributions in nuclear physics, nuclear power, metallurgy, mechanics, and chemistry; advances in physiology, biology, and psychology as well as an extremely wide range of developments in weapons controls, armament, amphibious warfare systems, underwater ordnance, aircraft instrumentation, undersea warfare—and in many related fields.

Typical of ONR's latest work is logistic support of the Earth Satellite Program, being carried on by ONR's Naval Research Laboratory. The entry of the satellite into space should bring many contributions in physics, geodesy, and geophysics, with many long range applications in transportation, communications, meteorology, navigation, mapping—and space travel.

This is one of a series of ads on the technical activities of the Department of Defense.

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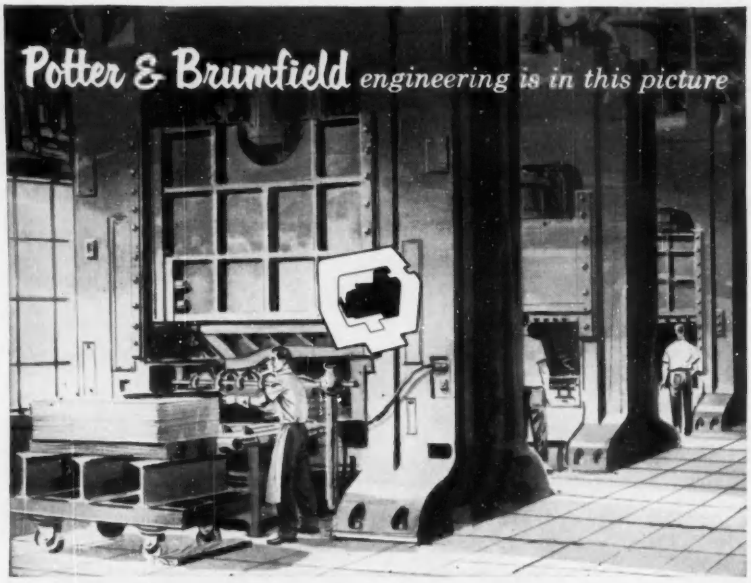

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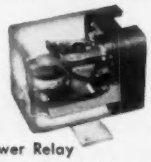

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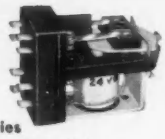

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Proper controls turn monsters into marvels . . . and controls are only as good as their components, such as relays. Without controls, this massive press, or any automated equipment, becomes a nightmare of disorganized force.

P&B AG Series relays are particularly suited to automation. They are ruggedly constructed for excellent shock resistance, withstanding 100 G shock without mechanical damage. The AG is a tough relay designed for rough jobs.

A metal enclosure keeps out shop dust and dirt. The phenolic base meets all U/L requirements for spacing and creepage distances . . . and the DPDT contact arrangement permits a wide variety of circuit variations.

For over 25 years, P&B has been building relays, and modifying existing types, to suit specific applications. Write for new catalog or engineering consultation.

P&B Standard Relays are available at your local electronic, electrical and refrigeration distributors

ENGINEERING DATA

SERIES: AG. Enclosed power relay for use in dusty or dirty applications.

CONTACTS: 3/16" dia. fine silver. Rated 5 amps., single break, 115 V. AC resistive. Rated 8 amps., double break, 115 V. AC resistive.

CONTACT ARRANGEMENTS: SPST NO-DM, SPST NC-DB, DPST-NO, DPST-NC, DPDT.

VOLTAGE RANGE: DC: 6 to 220 V. AC: 6 to 230 V.

COIL RESISTANCE: 30,000 ohm maximum.

POWER REQUIRED: 1.5 W. minimum DC at 25° ambient. 6 W. maximum.

AMBIENT TEMP. RANGE: —55° C. to +85° C.

TERMINALS: Screw type molded in phenolic base.

ENCLOSURE: Special dust cover.

DIMENSIONS: 2¾" L. x 2 11/32" W. x 3 5/32" H.

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bolic information; and the entire printing mechanism forming the plotted point is rotated. Any combination of these is also possible. Unit operates at rates of between 70 and 100 complete displays per minute. Applications include magnetic and gravimetric mapping, topographical surveying, trajectory tracing of ballistic and powered missiles, and plotting of aerodynamic pressures and stresses on solid sections.—Benson-Lehner Corp., Los Angeles, Calif.

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"ELECTROMETER"

The dual-purpose Model 225 dc VTVM couples a versatile dc amplifier with an extremely sensitive electrometer. It has eight ranges, from 30 mv to 100 volts full scale, and provides gains of 0.05 to 167. Line operated, the instrument features 10^{14} ohms input impedance and uses balanced circuits to drive a three-stage push-pull transistor amplifier. With available accessories, the Model 220 can measure voltages as high as 20 kv, currents down to 5×10^{-14}, and resistances up to 10^{16} ohms.—Keithley Instruments, Inc., Cleveland, O.

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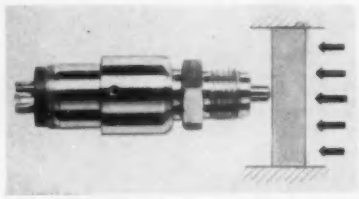
MEASUREMENT & DATA TRANSMISSION



NEW FORCE PICKUP

This new line of strain-gage force pickups measures loads in applications where the deflection is limited to 0.00035 in. Units are useful in measuring forces applied to rigid physical structures such as rocket-launching platforms, airframes, machine tool posts, and gun barrels. Pickups consist of a force probe, an unbonded strain gage, and an electrical connector. Ranges vary from 0 to 5 lb up to 0 to 2,000 lb. Excitation may be 6, 12, or

OPTIMIZING CONTROL discussed by *Manny Otis*

Industrial process control today generally consists of a series of unrelated minor control loops. Each loop measures but one variable at a particular time and controls excursions of this variable within predetermined limits from a set-point selected by an operator.

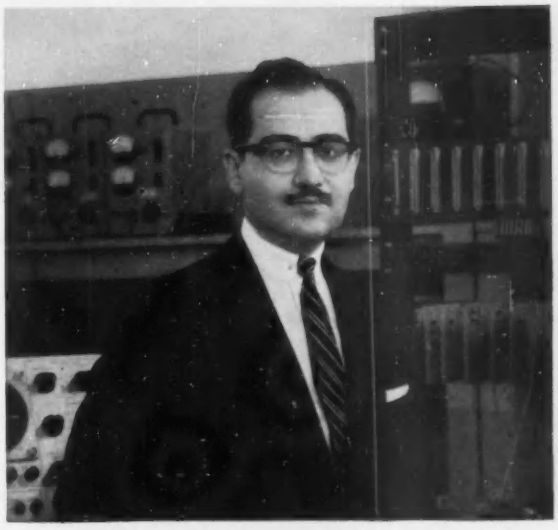
Trends within individual control loops are not obvious —that is to say similarities and dissimilarities in plant operating conditions are ill-defined—and the operator is unable to anticipate with sufficient rapidity interrelationships in such trends. This essentially precludes use of available data to the fullest advantage. Furthermore, it is easy to demonstrate that the limits within which a process variable can be held automatically are several orders of magnitude smaller than can be attained by a human operator in establishing the set-point for such limits. Hence, in making his decisions, the operator is at a marked disadvantage.

All of this leads us to the generalization that processes are controlled, but that the control function is not optimized. And as a rather natural extension of this generalization, if optimum control is incorporated into a process, the efficiency of the process can be expected to increase.

The first step toward this desirable objective has already taken shape with the development of electronic data logging systems. Many such systems are now available to industry. The unavoidable time lag between recording, correlation, and evaluation in such systems is so great, however, that the effectiveness of solutions provided for process control decisions is essentially nil. Hence, the data serve primarily to provide an insight into process dynamics.

In optimizing the continuous process, different variables must not only be sensed but correlated in real time in order to yield control decisions before plant operating conditions have changed appreciably. To achieve this, remedial control decisions must be initiated before the predetermined control-limits have been reached.

Progress in the theory of nonlinear adaptive control is providing the mathematical background necessary to define the necessary correlation procedures; digital computer techniques will play a decisive role in implementing the theory. Closing the loop in a continuous process, therefore, places tremendous demands upon the system's designer. A control system that is to replace a human being must be able to do so continuously and infallibly. Demands for ever greater reliability (one error in several hundreds of millions of decisions) and longer life are achieved with the use of solid state components. And since environmental conditions in industrial processes rarely are controlled as equably as in an office or a scientific computation center, circuit design and packaging requirements must be adapted to the widest range of operating climate.



Emmanuel J. Otis, systems design engineer discusses control optimization

The proper selection and integration of the necessary units required to "marry" the control computer to the process are dependent upon the desired speed and accuracy of the overall system. Hence, specific process requirements must govern the design of the control system in order to achieve the optimum use of equipment. These process characteristics must define speed, degree of accuracy, memory capacity, and flexibility—prime factors that determine the size and complexity, and therefore the price and economic justification for, such control equipment.

In closing the loop, digital computers and attendant devices will optimize industrial process control systems by providing minor control loop set-points. Eventually, minor control loops will be replaced altogether. At that time, control decisions will be made and operating instructions provided by the control equipment to devices that will govern the functioning of process variables.

The day of totally optimized control is not far off!

By applying the latest proven techniques, our well-qualified staff at Daystrom Systems is prepared to take single responsibility of assembling and installing a system to meet your needs. We are currently compiling a file of new applications and papers on various parts of systems, both industrial and military. If you are interested in receiving the file and periodic additions, please write us.

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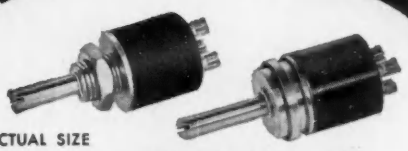

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UP TO 250 K

PRECISION POTENTIOMETERS

NOW YOU CAN specify a Waters pot for miniaturized designs that require potentiometers up to 250K. In the reliability-proved construction of the AP-½, these new, higher values give you:

- ***Resistances — 10 ohms to 250 kilohms***
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- ***Three terminal styles — radial, axial, or wire-lead***
- ***Automation models — for printed circuits***

General specifications: Centerless-ground, stainless-steel shaft can be sealed with O-ring; gold-plated, fork-type terminals standard; 2% standard linearity for 50K and above — 5% for lower values; temperature range −55 to +105C, to 125C on order; 2 watts at 80C; anodized aluminum body ½″ diameter × ½″ long — ⅝″ long for 100K and 250K; corrosion-resistant-alloy bushing; all electrical connections spot-welded or soldered; furnished with stops or for continuous rotation. *Write for data sheet on these dependable ½″ potentiometers.*

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Complete new family of
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NEW PRODUCTS

15 vac or dc.–Dynamic Instrument Co., Cambridge, Mass.

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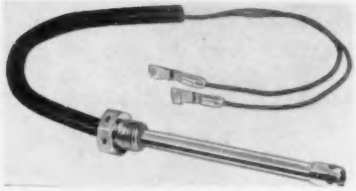

LOW-TEMP PROBES

Shown is one of a new series of probes designed to measure temperature changes in such diverse applications as liquid oxygen, guided missiles, and components in electronic circuits. Probes consist of thermistors mounted in tubes of stainless steel, aluminum, lucite, or other suitable material. Ranges available include: minus 185 deg C to minus 170 deg C; minus 20 deg C to plus 100 deg C; and 0 deg C to 60 deg C.–Gulton Industries, Metuchen, N. J.

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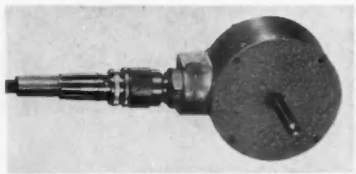


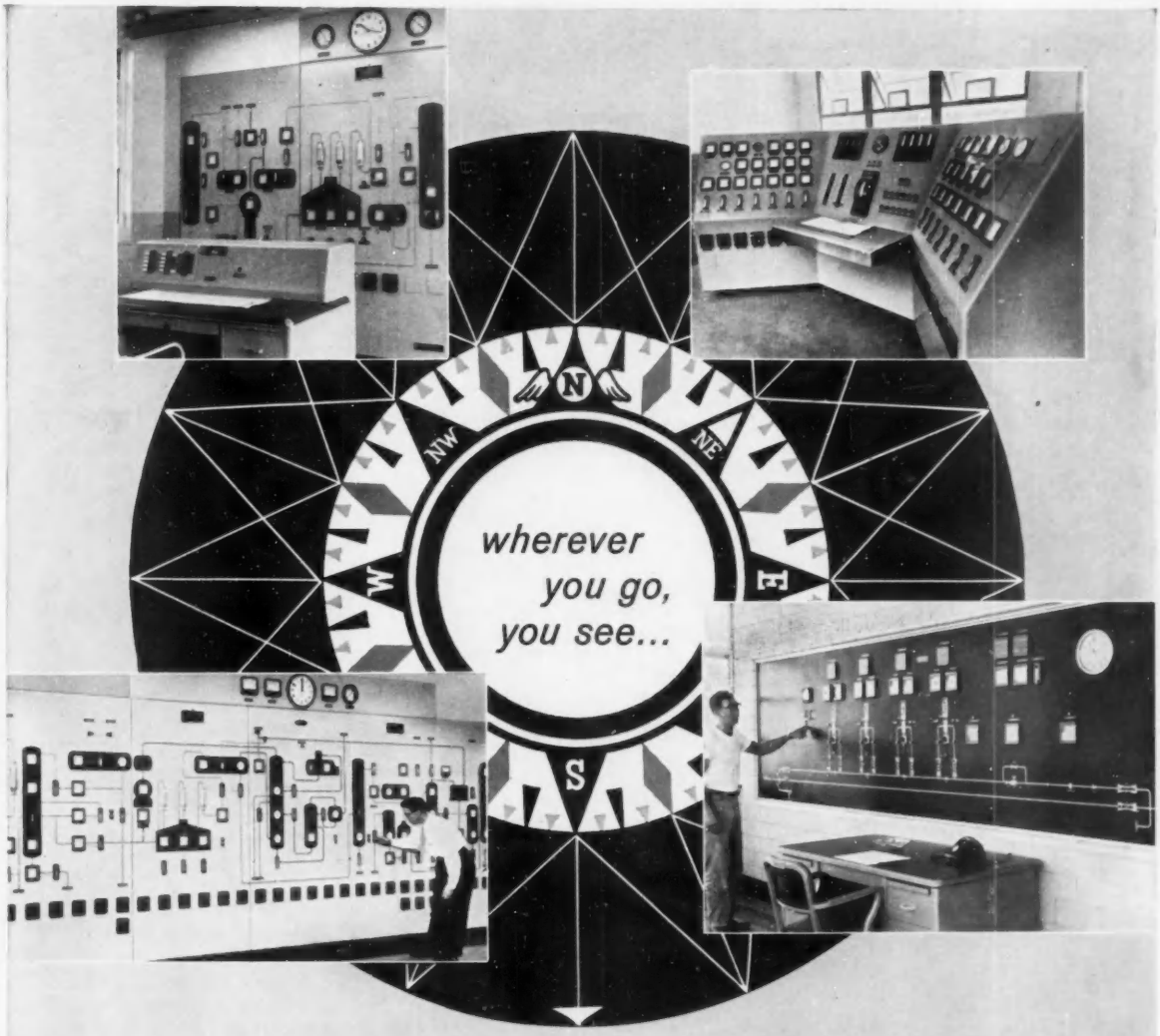
ROTARY TRANSDUCER

Type 70-BH rotary transducer shown here produces an output voltage directly proportional to shaft speed. Speeds of from 10 to 12,000 rpm can be accommodated at 60 counts per revolution. Unit is designed for both fixed mounting or offhand operation. It has a cast-aluminum housing, weighs 10 oz, and sells for $85 (including a 10-ft cable).–Dynapar Corp., Skokie, Ill.

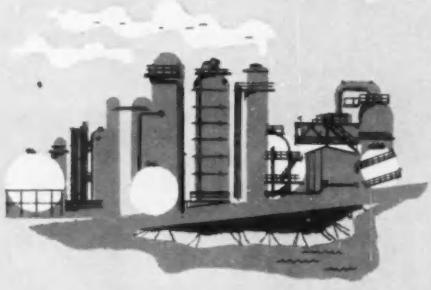
Circle No. 16 on reply card

NEUTRON DETECTORS

Two new neutron detector tubes for reactor control and reactor monitoring systems are now available. One, an enriched boron trifluoride proportional tube for counting thermal neutrons, comes in 1-in., 2-in., and 2⅛-in. diameters of various active lengths. Nominal operating voltage is 1,700, with



Swartwout AUTRONIC® CONTROL SYSTEMS



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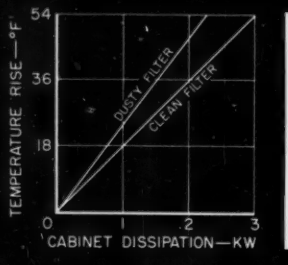
Roof Ventilators and Ventilating Louvers

THE SWARTWOUT COMPANY • 18511 EUCLID AVENUE • CLEVELAND 12, OHIO

Fan with Airfilter 1 to 3 KW Rejected with ROTRON Model RF Cooling Panel



- 2" thick Dustfilter
- 125° F. ambients
- Low noise level
- $49.75 from stock
- Also models with higher ratings and to MIL.Specs.

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WOODSTOCK • NEW YORK

NEW PRODUCTS

a 250-volt minimum plateau having a typical slope of 2 percent per 100 volts. The second model, of the recoil type for counting fast neutrons, has a polyethylene inner wall and an ethylene filling. Its operating voltage is 1,575 volts.—The Victoreen Instrument Co., Cleveland, Ohio.

Circle No. 17 on reply card

INFORMATION DISPLAY INSTRUMENTS

DP CONTROLLER

The Model 237 Controller, combining the features of this company's rupture-proof bellows unit with U. S. Gage's Pneumatic Pilot, is available in differential pressure ranges of from 0 to 20 in. water up to 0 to 50 psi. Static-pressure ratings are as high as 6,000 psi. Standard control actions include proportional with 1-to-150-percent adjustment, on-off, and differential gap. Reset action is optional with adjustment from 0.1 to 5.0 min per repeat. Unit takes a 20-psi supply pressure and has a 3-to-15 psi output (6-30 psi optional).—Barton Instrument Corp., Monterey Park, Calif.

Circle No. 18 on reply card

INDICATING REGULATOR

A new self-operating regulator features a front-mounted, 4-in. dial thermometer for accurate, easy-to-read temperature checks of the process being controlled. Regulator temperature ranges are available between 60 and 260 deg F with thermometer calibrations to match.—Powers Regulator Co., Skokie, Ill.

Circle No. 19 on reply card

FREQUENCY STANDARDS

*3⅛" high
400 - 1000 cy.

PRECISION FORK UNIT
TYPE 50

Size 1" dia. x 3¾" H. Wght., 4 oz.*
Frequencies: 240 to 1000 cycles
Accuracies:—
Type 50 (±.02% at —65° to 85°C)
Type R50 (±.002% at 15° to 35°C)
Double triode and 5 pigtail parts required
Input, Tube heater voltage and B voltage
Output, approx. 5V into 200,000 ohms

FREQUENCY STANDARD
TYPE 50L

Size 3¾" x 4½" x 5½" High
Weight, 2 lbs.
Frequencies: 50, 60, 75 or 100 cycles
Accuracies:—
Type 50L (±.02% at —65° to 85°C)
Type R50L (±.002% at 15° to 35°C)
Output, 3V into 200,000 ohms
Input, 150 to 300V, B (6V at .6 amps.)

*3½" high
400 to 500 cy.
optional

PRECISION FORK UNIT
TYPE 2003

Size 1½" dia. x 4½" H. Wght. 8 oz.*
Frequencies: 200 to 4000 cycles
Accuracies:—
Type 2003 (±.02% at —65° to 85°C)
Type R2003 (±.002% at 15° to 35°C)
Type W2003 (±.005% at —65° to 85°C)
Double triode and 5 pigtail parts required
Input and output same as Type 50, above

FREQUENCY STANDARD
TYPE 2005

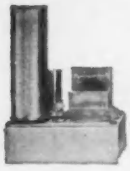
Size, 8" x 8" x 7¼" High
Weight, 14 lbs.
Frequencies: 50 to 400 cycles
(Specify)
Accuracy: ±.001% from 20° to 30°C
Output, 10 Watts at 115 Volts
Input, 115V. (50 to 400 cycles)

FREQUENCY STANDARD
TYPE 2007T
TRANSISTORIZED

Size 1½" dia. x 4½" H. Wght. 7 ozs.*
Frequencies: 240 to 1000 cycles
Accuracies:—Same as 2003, above
Type 2007S—Silicon type
Input, 28V.
Output, Multitap, 75 to 100,000 ohms
*3½" in 2007S, 400 to 800 cycles.

FREQUENCY STANDARD
TYPE 2121A

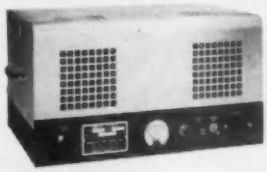
Size
8¾" x 19" panel
Weight, 25 lbs.
Output: 115V
60 cycles, 10 Watt
Accuracy:
±.001% from 20° to 30°C
Input, 115V (50 to 400 cycles)



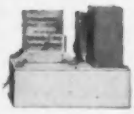
FREQUENCY STANDARD
TYPE 2001-2

Size 3¾" x 4½" x 6" H., Wght. 26 oz.
Frequencies: 200 to 3000 cycles
Accuracy: ±.001% at 20° to 30°C
Output: 5V. at 250,000 ohms
Input: Heater voltage, 6.3 - 12 - 28
B voltage, 100 to 300 V., at 5 to 10 ma.

FREQUENCY STANDARD
TYPE 211IC



Size, with cover
10" x 17" x 9" H.
Panel model
10" x 19" x 8¾" H.
Weight, 25 lbs.
Frequencies: 50 to 1000 cycles
Accuracy: (±.002% at 15° to 35°C)
Output: 115V, 75W. Input: 115V, 50 to 75 cycles.



ACCESSORY UNITS
for TYPE 2001-2

L—For low frequencies
multi-vibrator type, 40-200 cy.
D—For low frequencies
counter type, 40-200 cy.
H—For high freqs, up to 20 KC.
M—Power Amplifier, 2W output.
P—Power supply.

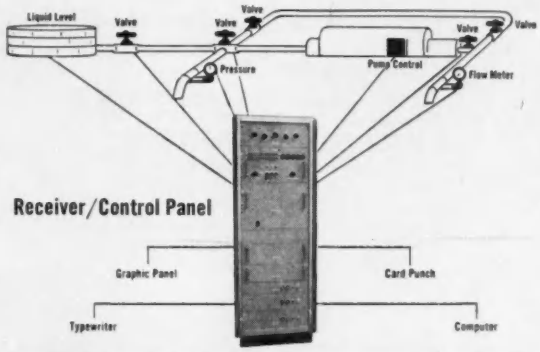
This organization makes frequency standards within a range of 30 to 30,000 cycles. They are used extensively by aviation, industry, government departments, armed forces—where maximum accuracy and durability are required.

WHEN REQUESTING INFORMATION
PLEASE SPECIFY TYPE NUMBER

American Time Products, Inc.

580 FIFTH AVENUE, NEW YORK 36, N. Y.

Automatic Monitoring and Control of ANY Remote Pipeline Operation



with

Bendix-Pacific

ELECTRO-SPAN

THE LOW COST DIGITAL SYSTEM

Electro-Span Systems are accurate, reliable digital data transmission systems for pipeline telemetering and supervisory control.

Any number of remote pump stations or functions can be controlled from one or more control locations with these Bendix engineered systems.

The functions of control, indication, data-logging, and monitoring can be provided singly or in combination, providing the most accurate, efficient and inexpensive use of standard communication links.

Write for the new brochure which fully describes these pipeline supervisory control and data-logging systems. Please request Bulletin ES-12.

VERSATILE TANK GAUGING SYSTEMS

Any number of tanks can be measured and controlled by the Bendix digital pulse-code system. The receiving equipment can indicate tank liquid level in feet, inches and eighths as well as temperature by tank number and can scan several tank farms automatically. Write for Bulletin ES-5A for full information.

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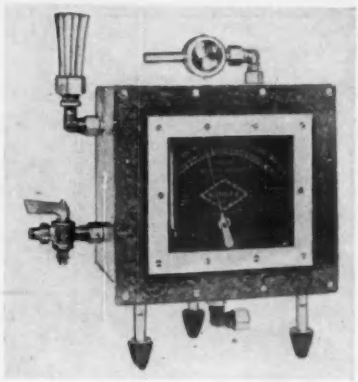
NEW PRODUCTS



HUMIDITY INDICATOR

Designed for remote indication of relative humidity, this new instrument has a guaranteed accuracy of plus or minus 1.5 percent. Two connections are all that is required to put the unit in operation. Primary element consists of an extremely sensitive animal membrane tissue. Other features: built-in temperature compensation, double-wall aluminum construction.—Serdex, Inc., Boston, Mass.

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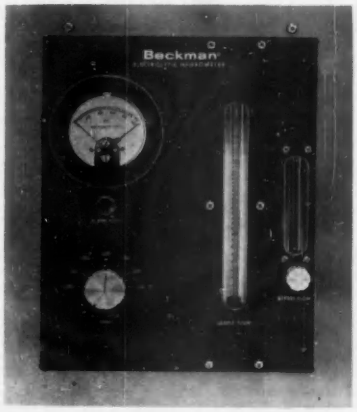
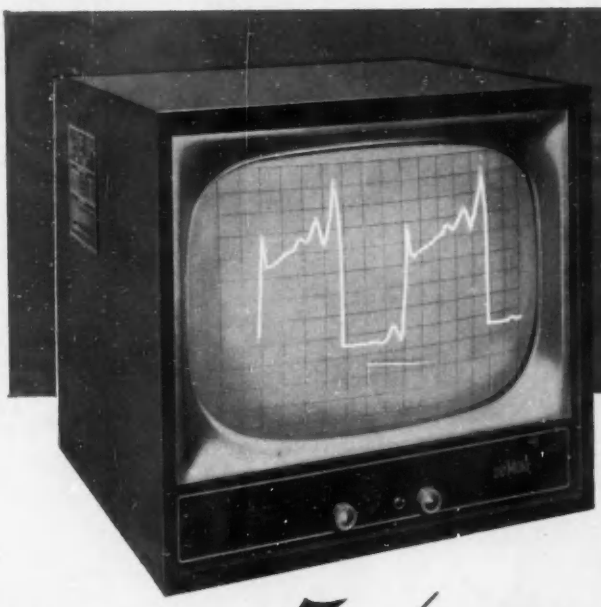


NEW HYGROMETER

This unit automatically and continuously measures water concentrations in vapor samples in the difficult 0 to 1,000 ppm range, with a 95-percent accuracy. Applications would include controlling corrosion, product purity, and process efficiency. Incorporated is an alarm system that can be set for any point in the instrument's range. A standard potentiometer recorder (or recorder-controller), 10 or 50 mv, can be operated by the output. An-



21"

SlaveScope

- FOR LECTURES
- DEMONSTRATIONS
- PRODUCTION LINE TESTING
- COMPUTER READ-OUTS, ETC.

Show the patterns big, bright and clear . . . so everyone can see!

The Du Mont SlaveScope may be used with any standard low-frequency oscilloscope for applications such as group viewing, production line testing, or computer read-outs. Signals from the deflection plates of the driving oscilloscope are fed through a cathode-follower adapter to the SlaveScope. The oscilloscope pattern is accurately reproduced on the large screen of the SlaveScope.

The SlaveScope is supplied with a 10' connecting cable, but may be used for remote viewing up to 100' from the driving oscilloscope.

ACCURATE REPRODUCTION: X and Y amplifier linearity of 1% full scale.

HIGH VISIBILITY: Accelerating potential of 6 KV produces bright trace, even under high ambient light conditions.

DEFLECTION FACTOR: Dependent upon driving oscilloscope. For example, when used with Du Mont Type 401, 100 millivolts full scale; when used with Type 403, 1 millivolt full scale.

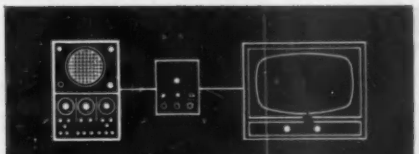
FREQUENCY RESPONSE: DC to 100 KC, dependent upon deflection amplitude.

IDENTICAL AMPLIFIERS: Identical X and Y amplifiers.

TYPE 343 17" rectangular CRT, rack mounted **$980.00**

TYPE 345 21" rectangular CRT, for bench use **$870.00**

(with P4 screens. P1, P2, P7 screens available at slightly higher cost.)



For coupling SlaveScope to master oscilloscope, Type 2622 Cathode Follower Adapter prevents loading of deflection circuits, assuring accurate reproduction of test patterns. Type 2622, $105.00

Signals from high output, low-frequency transducers may be fed directly into SlaveScope. X and Y amplifier sensitivity 1 volt/inch.

SlaveScope used with Type 2628 Amplifier-Sweep Adapter as a complete, laboratory quality, general purpose low-frequency oscilloscope.

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PHILBRICK PLUG-IN DC

AMPLIFIERS

AVAILABLE FROM STOCK

For a wide variety of instrumentation and control problems, you can facilitate rapid set-up with either one or both of these octal-based, plug-in Philbrick Amplifiers. Operational Amplifier, Model K2-W, features balanced differential inputs for minimum drift and maximum utility. In conventional applications, overall amplifier characteristics are affected solely by the feed-back networks, since the two inputs can be maintained at nearly equal potential with appropriate feed-back circuitry.

For more critical applications where long term drift must be reduced to sub-millivolt levels, Stabilizing Amplifier, Model K2-P, is paired with Model K2-W. *Write for free 28 page Plug-In Amplifier Applications Manual-10.*

MODEL K2-W	MODEL K2-P
GAIN: 15,000 dc, Open Loop	GAIN: 1,000 dc
POWER REQUIREMENTS: 4.5ma @ ±300 vdc, 0.6 amps. @ 6.3v	POWER REQUIREMENTS: 2.4 ma @ +300 vdc, 0.45 amps. @ 6.3 vac, 60 cps
OUTPUT RANGE: +50v. to −50v. at 1 ma	INPUT IMPEDANCE: 1 Megohm
RESPONSE: 2 Microseconds rise time, 100 Kc with unity feed-back	STABILITY: Below 100 Microvolts
PRICE: $24.00 Postpaid	PRICE: $60.00 Postpaid

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NEW PRODUCTS

alysis is performed by continuously passing a sample gas stream through a special analytical element that absorbs and electrolyzes all moisture present. The current required for this electrolysis is a precise measurement of the amount of water present. —Beckman Instruments, Inc., Fullerton, Calif.

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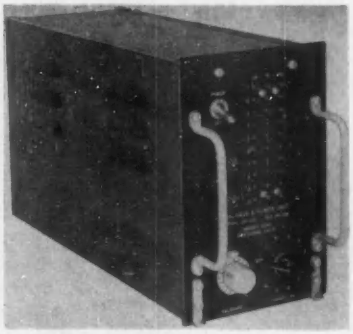

TEMPERATURE MONITOR

Powered and operated entirely by magnetic amplifier circuitry, the Model CTI-10D monitors up to 10 channels of temperature simultaneously. By means of balance and sensitivity adjustments, each channel can be set for any desired critical temperature range and trip point. The complete system is designed as an aircraft safety device and consists of an indicator panel, visible to pilot or chief engineer; balance and power unit, shown above; and temperature probes with interconnecting cables. System meets environmental specification MIL-E-5272. — Arnoux Corp., Los Angeles, Calif.

Circle No. 22 on reply card

CUTS PARALLAX ERROR

A line of indicating pyrometers may now be read more accurately from all angles because they have been redesigned with mirror scales to reduce parallax effect. These medium resistance pyrometers (4 ohms per mv) are available in 21 standard ranges. Maximum sensitivity for a pyrometer connected to one thermocouple is 300 deg F for full-scale deflection. Full-scale accuracy of 2 percent is standard; 1 percent is available at extra cost. Panel mounting, portable, and bench models are available.—Assembly Products, Inc., Chesterland, Ohio.

Circle No. 23 on reply card

What goes on inside the potentiometers you buy? The working parts look simple enough – but only rigid testing can predict how they will perform in service. Fairchild's comprehensive quality control program assures you of *dependable* performance. At the left, a typical continuous recorder trace shows how the linearity of Fairchild potentiometers is verified. Every Fairchild unit is also tested for noise, voltage breakdown and total resistance. And every type is completely tested in our own environmental testing laboratories.

LOWEST ULTIMATE COST

How potentiometer and system costs depend on performance

The lowest ultimate cost of your electronic system can hinge on your selection of reliable potentiometers from a dependable manufacturer. You want to design the system to take full advantage of the potentiometer's capabilities. But you can't do this if potentiometer performance is variable. Consistent performance means meeting your specifications, whether you're buying samples or production quantities. It also means standing up to the environmental and life factors of your application.

Reliability is the key to lowest ultimate cost and you can only get that with quality design, manufacturing skill and *quality control.*

That's why Fairchild insists on incoming materials inspection, sub-assembly and final inspection, plus performance testing, and environmental testing to destruction of random samples. Thus, no matter what factors govern your choice of potentiometers, you'll find the lowest ultimate cost in Fairchild's complete line.

Write for catalog to Dept. 140-84C, Fairchild Controls Corporation, Components Division:

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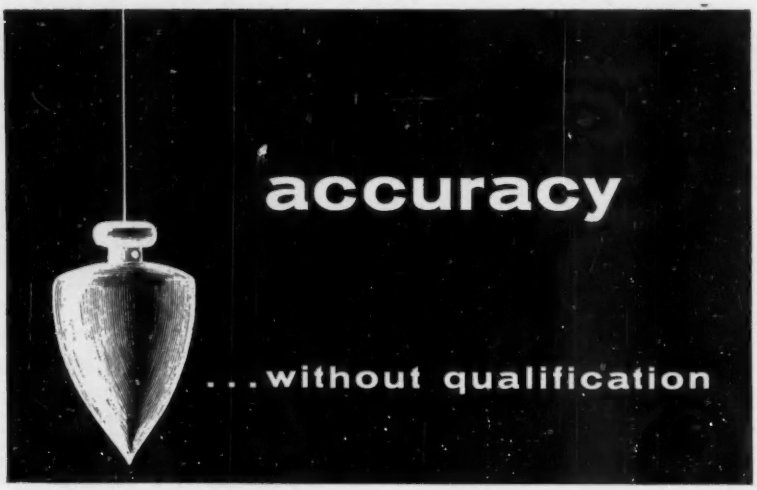
FAIRCHILD
PRECISION POTENTIOMETERS and COMPONENTS



Absolute Pressure Measurement

Manometers are ideally suited to absolute pressure measurement applications. The raised-well type (left) is adjusted for prevailing barometric pressure; the sealed-tube type (right) is self-compensating for barometric pressure changes. Both read directly in terms absolute.

With other forms of instrumentation, you wonder. With the manometer, you know . . . accuracy is unqualified; it's timeless.

There is never a question of calibration or re-calibration. Whether it is brand new or years old, a manometer is *never* in error. It is operated by the force of gravity, and gravity never fails.

It is only this type of accuracy that offers true reproducibility for the plant engineer and reliable data for the laboratory technician.

Despite this perfect accuracy, the Meriam Manometer is lowest in cost . . . simplest to maintain of all instrumentation forms.

NEW

. . . complete and informative guide to manometer theory and practice as well as manometer models for plant, field and laboratory use. Just ask for Bulletin G-14. The Meriam Instrument Company, 10920 Madison Avenue, Cleveland 2, Ohio.

FLOWS PRESSURES VACUUMS LEVELS DIFFERENTIALS

MERIAM MANOMETERS

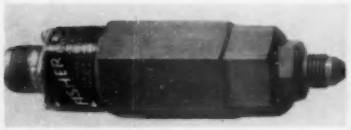
...always accurate

CONTROL DEVICES

NEW BLENDING CONTROL

The instrument shown here, called the Blendtrol, will maintain flow rates in closed-loop systems or blend and proportion in open-loop systems. It blends by maintaining a preset ratio between two components. The flow of the major component is measured and an electric signal transmitted to the controller. The ratio is applied to this signal and an output signal is produced that will control the flow of the additive or minor component. Total system cost, less installation, is $1,500. —The Jordon Co., Inc., Milwaukee, Wis.

Circle No. 24 on reply card



PRESSURE SWITCH

This new in-line, piston-type pressure switch, designed for hydraulic and pneumatic systems, is unaffected by jarring or vibration. Standard units have $\frac{3}{8}$ in. male tube or $\frac{1}{4}$ in. male pipe connections, and an AND electrical connection. Maximum pressures range from 100 to 3,500 psi. Units weigh about 3 oz, measure 3 in. in length, and have an electrical rating of 15 amps at 120 vac. — Fisher Controls Inc., Santa Monica, Calif.

Circle No. 25 on reply card

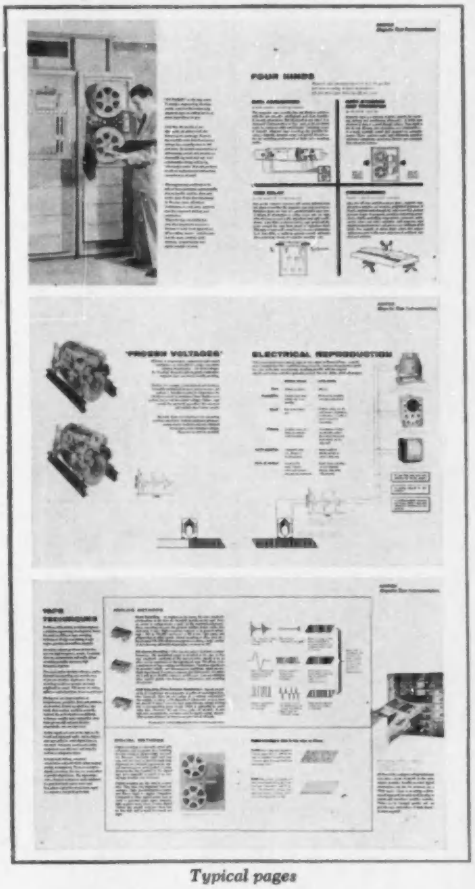
STACKING SWITCH

Up to 20 poles can be stacked in a new multiple stacking switch. The unit consists of a number of sections held together by V-band clamps. The end of the shaft in one section fits integrally with the end of the shaft in

How to be a magnetic tape recording expert

Introducing a useful new brochure on tape in instrumentation

Tape is the stuff of which memories are made — the versatile data memories for a jet propelled age of electronic miracles. If you are one who keeps up with times and techniques, it is a field well worth knowing. This new brochure gives a wide-angle view of the whole subject.



Typical pages

What kinds of applications do you think of when magnetic tape recording is mentioned? Sound recording, of course, and telemetering, if you are in that business. But what about simulating a rough road to test truck axles, controlling a milling machine to cut an aircraft wing section out of a solid billet, monitoring for a sudden occurrence that may happen only once in a year or two, recording data that can be reduced to graphs and tabulations without ever being touched by human hands? These and many more are described.

How significant is the fact that magnetic tape recording reproduces data in the same electrical form in which it was recorded? Enormously important, when you realize all the things the reproduced data can do that couldn't be done with the original signals or with the common forms of visual recording. For example the data can be slowed down to look at fast transients. It can be speeded up for wave analysis. It can be read out in any form. A tabular comparison between original signals and taped signals gives the full story. And a step-by-step pictorial demonstration of magnetic tape recording and reproduction puts the electrical-data idea into tangible, easily visualized form.

What does the data on magnetic tape look like? You can't see it, but the brochure will give you an idea of what it would be like if you could. And incidentally this may help to clarify the differences between various magnetic-tape-recording techniques.

Do you talk in tape's language? When is a tape recorder not a recorder? What is the difference between a channel and a track? What is a servo speed control? A much needed glossary gives the consensus of our views on terms.

For whom did we write this booklet . . . the expert, or the man for whom the whole subject is new? Both. It is written and illustrated so that any engineer or technically trained person can readily grasp the concepts and gain a broad understanding of the subject. If you are one of those who has already worked extensively with tape, you will find some new twists in the way the subject is explained, and perhaps ideas on new areas you hadn't explored. And incidentally, a copy of this brochure in some handy file will give you a good start in indoctrinating that new man in the department.

For your copy, write us today on your company's letterhead. Address your request to Department HH-5.

INSTRUMENTATION DIVISION
AMPEX CORPORATION
FIRST IN MAGNETIC TAPE INSTRUMENTATION
934 CHARTER STREET · REDWOOD CITY, CALIFORNIA

District offices serving all areas of the United States and Canada; Foreign Representatives in countries around the world.

Shot in the Dark!

Wide Area Infrared Detection System Pinpoints Important Target Areas

Manhattan at 10 P.M. This is how the city looks to a passive infrared detection system. The brightest spots reveal the areas of greatest activity... the brightness of each spot on the map below is a function of its temperature. Recently declassified, this photograph was taken in 1951 (using panchromatic film) with equipment manufactured by Servo Corporation of America. At that time, Servo Corporation had already solved the problems of wide area infrared detection.

SERVO CORPORATION OF AMERICA

20-20 Jericho Turnpike
New Hyde Park, L.I., N.Y.

Infrared Temperature Control for Industry

Servotherm® Pyrometer Systems, manufactured by Servo Corporation of America are solving industry's problems of automatic temperature control for processes and manufacturing operations that do not permit direct contact. Servotherm Systems feature:

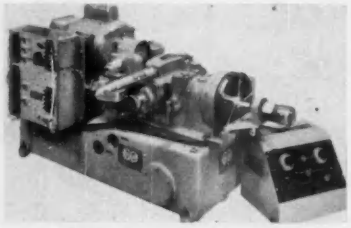
- **Remote Detection — wherever there's a line of sight, there's measurement**
- **Quick Response — .250 seconds even at the lowest level of sensitivity**
- **Accuracy — temperature is measured within the limits of ±1%**
- **Sensitivity — temperature variations as small as 0.10°F are detected.**

To learn more about Servotherm Systems, please request on your company letterhead TDS-TRPS-2.

NEW PRODUCTS

the adjoining section, so no couplings are needed. Each section contains two contact plates. Phasing of the plates is done by a screw adjustment. Switch speeds range to 600 rpm.—Applied Science Corp., Princeton, N. J.

Circle No. 26 on reply card



PRECISE SPEED CONTROL

Called the Electro-Hydraulic Servo Controlled "Any Speed" Drive, this unit is designed for precision speed control from zero to maximum rpm and for positive follow-up position control from a remote command unit. Accuracies within 0.1 to 1.5 percent can be expected over the output speed range. For position control, precise stopping positions can be selected at will from an infinite range of 360 deg. —The Oilgear Co., Milwaukee, Wis.

Circle No. 27 on reply card

VERTICAL GYRO

The WG-2 gyro, shown here with cover removed, provides accurate and reliable two-axes vertical reference data in the form of two synchro output signals. It is hermetically sealed against sand, dust, moisture, salt spray, etc., and has a shock and vibration resistant construction. Vertical repeatability is to within 10 min of the

AC BREAKS THE ACCURACY BARRIER WITH...

A giant T-square laid from here to any spot on earth couldn't plot a missile's flight with greater accuracy than AC's new inertial guidance system!

This is a new concept in inertial guidance—made possible by a new type of gyro stabilization of fantastic precision.

This virtually frictionless system provides the stable platform needed for pinpoint accuracy over thousands of miles of flight.

With the ACHIEVER, AC engineers' long experience in translating dreams into electronic circuits has contributed vital guidance to the top-priority Air Force ballistic missiles in America's arsenal of defense. AC electro-mechanical and production experience is ready and able—right now!

GM GENERAL MOTORS

AC

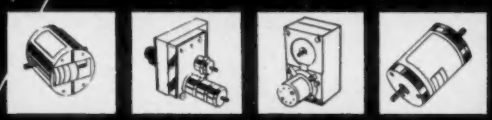
THE ELECTRONICS DIVISION OF GENERAL MOTORS
FLINT, MICHIGAN • MILWAUKEE, WISCONSIN

BOWMAR PRECISION ELECTROMECHANICAL ASSEMBLIES

The design and production of ultra-precision electromechanical control assemblies are Bowmar specialties. This tiny package, which fits easily into the palm of one's hand, performs a vital control function in one of the nation's "hot" missile projects.

Bowmar offers a custom service in the design and fabrication not only of such complete assemblies, but also of the precision components which comprise them: Counting Devices, Speed Reducers, Gear Heads, Housings, Special Adapters and Precision Accessories.

This miniature Bowmar control assembly is actuated by a Size 8 motor, which drives a potentiometer through a precision Bowmar gear train. A special Bowmar slip clutch prevents damage to pot stops. Gears are precision-machined; shafts and pinions are mounted in Class 5 ball bearings. (Developed and manufactured for EPSCO, Incorporated.)



SEND FOR "PRECISION ELECTROMECHANICAL COMPONENTS" PORTFOLIO

PRECISION ELECTROMECHANICAL ASSEMBLIES, PRECISION SPEED REDUCERS, GEAR HEADS & MECHANICAL COUNTERS.

Bowmar INSTRUMENT CORP.

2200 PENNSYLVANIA STREET • FORT WAYNE, INDIANA

NEW PRODUCTS

arc cone and the initial erection. Unit has unlimited altitude capabilities and a 1,000-hr minimum operating life.—The Waltham Watch Co., New York, N. Y.

Circle No. 28 on reply card

REGULATES 1 KVA

The Model TM7101 Automatic Voltage Regulator ($475, less cabinet) contains no tubes, transistors, or moving parts, takes a 95-to-135-volt single-phase input, and has a nominal 115-volt output (adjustable from 110 to 120 volts). Response time is less than 0.5 sec for ordinary line and/or load variations. For extreme line and load changes, maximum response is 1.0 sec. It will accommodate loads up to 1.0 kva; power factor is 0.5 lagging to 1.0.—Superior Electric Co., Bristol, Conn.

Circle No. 29 on reply card

COMPACT CONTROLLER

The Transcope Pneumatic Controller provides an accurate, compact means of maintaining a given set-point: it relays measured variables for subsequent corrective action. Operation is on the motion balance principle through interconnected multiple bellows and springs acting on a common

EDISON resistance temperature detectors

provide time constant of less than $\frac{1}{2}$ second

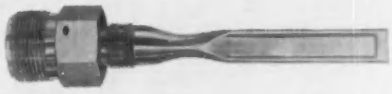
SPECIAL EDISON DESIGN PROVIDES HIGH RATE OF HEAT TRANSFER

An instantaneous response to a change in temperature in monitoring of a guided missile or a motor sleeve bearing could mean the difference of many thousands of dollars in equipment and time. Edison Resistance Temperature Detectors are specifically designed to reduce lag time. Time constants as high as 0.25 seconds have been obtained in special types.

Edison engineers designed these Detectors with rapid heat transfer in mind. The basic element, a low-mass chemically pure nickel or platinum wire, is inherently fast to respond to temperature changes. Couple this fact with such design refinements as using ceramic bushings to cover the fine wire element so that only the tip is exposed to the temperature . . . or providing spring-loaded holders to insure close contact between the detector tip and the surface being measured . . . and flattening the stem, in one instance, so that the heat transfer is more rapid.

These refinements in design are representative of Edison's experience and know-how in temperature control. Other very important features of Edison Resistance Temperature Detectors are elimination of the need for signal amplification, high accuracy and exceptional stability, and hermetically-sealed corrosion-resistant steel wells.

Your need for temperature control means a need for Edison Resistance Temperature Detectors. Write today for complete details. Please state your application.



MODEL 235N90-3S
Designed for fast response and high resistance to the corrosive effects of rocket fuels used in guided missiles.
SPECIFICATIONS:
Stem-sensitive.
Useable temperature range —70° to +200°C.
Exponential time constant in agitated waterbath 0.8 second. Maximum hydrostatic pressure on stem: 750 psi at 100°C.
Basic resistance at 0°C = 90 ohms.
Hermetically sealed.

MODEL 242P
This Detector can be operated in live steam or high temperature atmospheres up to 1300°F.
SPECIFICATIONS:
Stem-sensitive.
Useable temperature range —70° to +750°C.
Maximum hydrostatic pressure on stem: 300 psi at 750°C.
Basic resistance at 0°C = 100 ohms.
Hermetically sealed.

MODEL 230N
A general purpose Detector for temperature measurement and control in industrial processes.
SPECIFICATIONS:
Stem-sensitive.
Basic resistance at 0°C = 120 ohms.
Hermetically sealed.

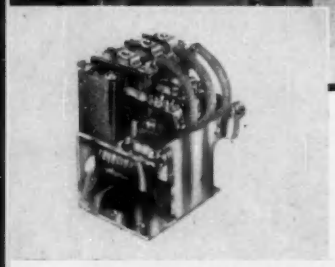
MODEL 166NC
Element is concentrated in tip for sensitivity to surface temperatures in motor bearings, etc.
SPECIFICATIONS:
Tip-sensitive.
Useable temperature range —70° to +300°C.
Basic resistance at 0°C = 120 ohms.

McGRAW EDISON

Thomas A. Edison
INDUSTRIES
INSTRUMENT DIVISION
38 LAKESIDE AVE. WEST ORANGE, NEW JERSEY

GN

"our design is frozen.....
the order went to the
MAN FROM
PHILLIPS"



COIL CHARACTERISTICS:
Operating Voltage: Up to 300 volts D.C.
Up to 450 volts A.C., 60 cycles
Resistance: Up to 12,000 Ohms.
Operating Current: 0.007 Amps., D.C., minimum
Operating Time: 0.010 Seconds, minimum

CONTACT ASSEMBLY:
All forms A, B, or C plus double makes, breaks, and transfers. Code number 13 or 14 silver contacts, standard. Other contacts available.

MOUNTING:
Frame Tapped for four #6-32 mounting screws

VARIATIONS:
Quick disconnect terminals
Latching Assemblies
Plug-in Assemblies
Enclosed Assemblies, removable covers
Hermetically-sealed Assemblies

Put your relay problems 'on ice' Particularly suited for general control and timing circuits, the Type 33B power-type relay provides the long life and extreme reliability required for your most critical applications. For maximum efficiency, the frame, armature and core are manufactured from high grade magnetic iron and the armature operates on phosphor bronze bearing pins. Its stationary contacts are mounted on molded phenolic blocks while the movable contacts are carried on phosphor bronze blades. All contact blades may be individually set with adjusting screws. Coils are precision-wound on non-corrosive bobbins. For A.C. operation, silicon iron parts and copper shading rings on the coils are standard features.

Whatever your relay stumper—multi-contact, power or hermetically-sealed—the *man from PHILLIPS* can help you.

HERMETIC SEALS, MULTI-CONTACT, POWER, HERMETICALLY SEALED RELAYS, ACTUATORS

PHILLIPS

PHILLIPS CONTROL CORPORATION . . . JOLIET, ILLINOIS

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NEW PRODUCTS

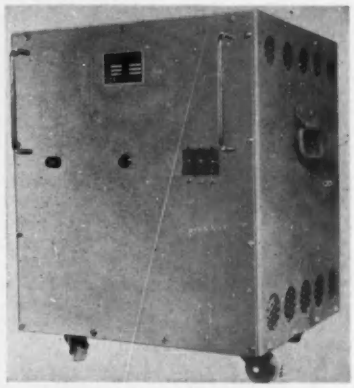
force plate. Though primarily designed for mounting behind a panel, its plug-in feature permits mounting to a separate manifold located either at the point of measurement or at the point of control. The unit, available with single or multiple control responses, measures 6 in. by 6 in. by 4½ in.—Taylor Instrument Co., Rochester, N. Y.

Circle No. 30 on reply card

COMPACT SWITCHES

The Class 4 TyniSwitch, designed for applications requiring high electrical rating in a small precision snap switch, is actuated by operating forces of from 3 to 12 oz. Units are available with solder, screw, standard spade, or Junior tab terminals. All are UL listed at 15 amps, 125 to 250 vac. Models are available with four different actuating means.—Detroit Controls Corp., Bridgeport, Conn.

Circle No. 31 on reply card



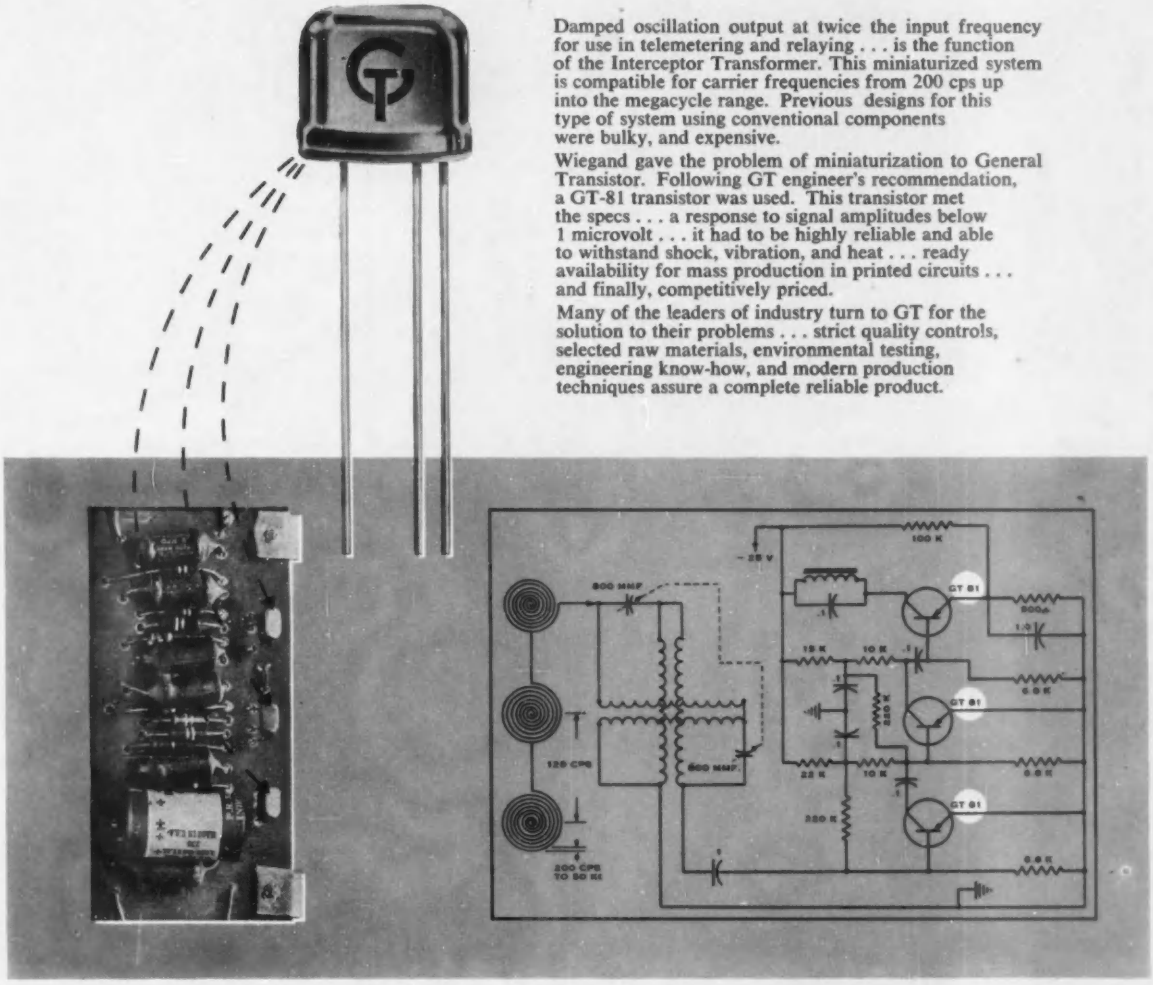
INDUSTRIAL AUTOMATION

This 1,000-watt magnetic servo amplifier for industrial control applications features 1-cycle response and both reference- and control-phase power for a ¾-hp motor. Applications include milling machines and other 60-cycle equipment, and programmed processes. The MB-1000-60 incorporates a Scott-connected transformer. It has no toroids. Primary use is in 220-volt, three-phase operation, although 115-volt, one- or two-phase operation is possible with simple factory modification. Wheeled cabinet measures 20 in. high, 16½ in. deep, and 17 in. wide.—Magnetic Research Corp., Hawthorne, Calif.

Circle No. 32 on reply card

GENERAL TRANSISTOR

AIDS LOW-COST MINIATURIZATION OF WIEGAND MFG. CO.'S INTERCEPTOR TRANSFORMER



Damped oscillation output at twice the input frequency for use in telemetering and relaying . . . is the function of the Interceptor Transformer. This miniaturized system is compatible for carrier frequencies from 200 cps up into the megacycle range. Previous designs for this type of system using conventional components were bulky, and expensive.

Wiegand gave the problem of miniaturization to General Transistor. Following GT engineer's recommendation, a GT-81 transistor was used. This transistor met the specs . . . a response to signal amplitudes below 1 microvolt . . . it had to be highly reliable and able to withstand shock, vibration, and heat . . . ready availability for mass production in printed circuits . . . and finally, competitively priced.

Many of the leaders of industry turn to GT for the solution to their problems . . . strict quality controls, selected raw materials, environmental testing, engineering know-how, and modern production techniques assure a complete reliable product.

This is one more example why
General Transistor is the fastest growing name in transistors.
Send for Bulletin G-110.

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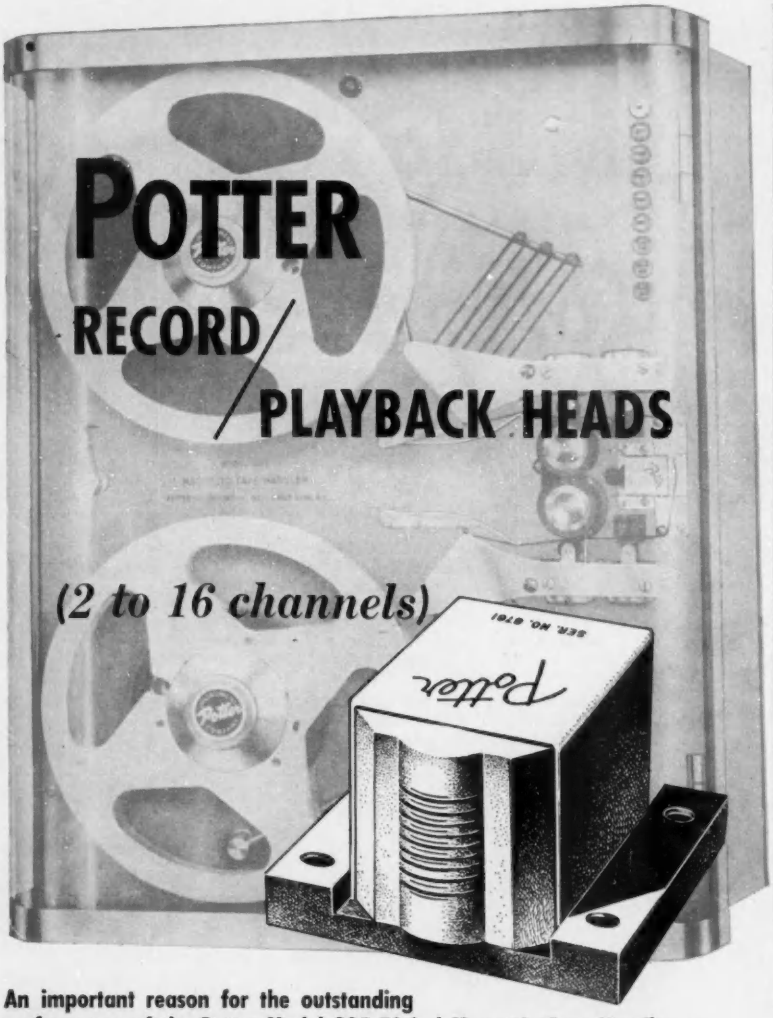
CORPORATION
91-27 138TH PLACE JAMAICA 35, NEW YORK



An important reason for the outstanding performance of the Potter Model 905 Digital Magnetic Tape Handler

Precision designed to meet highest standards of performance and reliability... *machined bronze... solidly constructed to close tolerances... high dimensional stability... full shielding between channels... precisely aligned gaps.*

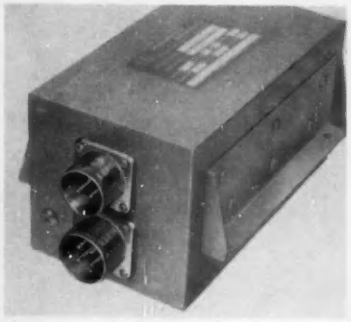
Track width:	.020" to .031" ± .001"
Track spacing:	.050" to .078" ± .001"
Gap width:	.0005"
Gap alignment:	Within .0001"
Inductance:	Nominal 10 mhy for tube record amplifiers Nominal 1 mhy for transistor record amplifiers *(Available with both high and low impedance windings on each channel)*
Record Current:	10 mhy: 10 ma. 1 mhy: 30 ma. Rise time: 1 μ sec
Signal level:	Nominal 10 mv. for 10 mhy winding at 30 ips
Signal/noise:	Full shielding gives playback S/N 40 db or better

Gap, track width, track spacing and nominal inductance can be varied within reasonable limits for custom applications.

For more information, prices and delivery schedules on heads and tape handlers, write, wire or phone your Potter representative or the factory.

POTTER INSTRUMENT COMPANY, INC.
115 Cutter Mill Road Great Neck, L. I., N. Y.

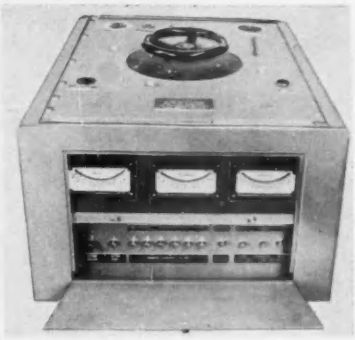
POWER SUPPLIES



LOW-VOLTAGE AC/DC

A new line of low-voltage ac/dc power supplies, engineered to deliver precise plate voltage to aircraft electronic systems, is designed for 440-cycle operation but can supply 60-cycle circuits. The hermetically sealed telemeter and steam gage magnetic units have no moving parts and are self-protected for shorted output. Thus they do not require a fuse. Other features: regulation within plus or minus 0.2 percent, ripple of 1 percent rms, recovery time of 0.5 sec, and a variety of outputs.—Engineered Magnetics Div. of Gulton Industries, Inc., Metuchen, N. J.

Circle No. 33 on reply card



ADJUSTABLE AC POWER

A series of five adjustable-voltage, metered power supplies, providing a self-contained, compact source of adjustable ac voltage combined with laboratory quality instrumentation, is now available. At present only 60-cycle models for 120 and/or 240 volts are stocked, but 400-cycle models are on the way. Eight current ranges, from

FISHER®

Series 2800

Liquid Level CONTROLS

For use as high and low limit switches, to sound alarms, flash signal lights, start or stop fluid transfer pumps, or to operate control valves.

Series 2800

Series 2800 are dependable, inexpensive, snap acting liquid level controls. They are float actuated and, for maximum versatility, are available with either electric (explosion-proof) or pneumatic switch action. Either pilot type is interchangeable on the same float housing assembly. Stab-in type of tank mounting provides easy installation. Available with 4" iron or steel flanged tank connection. Write for Bulletin F-2800 for complete information.

FISHER GOVERNOR COMPANY

Marshalltown, Iowa • Woodstock, Ontario

RVF ROTARY SWITCH

wholly
NORTH
manufactured

Rotor easily removable for cleaning or maintenance
Bank easily accessible for cleaning
Completely dust enclosed
Built-in spark suppression on self-driving contacts
Built-in shock mounting

The RVF Rotary Switch is available up to a maximum of 6 levels, 30 points, with single wiper. With double wipers, provides 12 levels with 15 points.
Bank contact ratings: 1 amp. at rest; .2 amp. resistive when stepping. Off normal contact ratings .4 amp. resistive.
Switch may be driven self-stepping or externally.

Mounting dimensions: 1.968" x 3.661" O.C.
Overall height: 4¾"; height above mounting, 3½" (max dimensions for 6 level switch).
Weight: 1.32 lbs.

Since the introduction of the L. M. Ericsson RVF Rotary Switch by North Electric Company, it has gained nationwide acceptance as the outstanding Rotary Switch available.

The constantly increasing domestic demand for the RVF Rotary Switch will now be met by North Electric's virtually unlimited production facilities, where the switch is being wholly manufactured, not only in all the standard types to which the industry is accustomed, but also in variations specifically designed to meet your application needs.

This represents another most significant step in North's program to provide a single source facility for all types of industrial switching components.

INDUSTRIAL DIVISION

NORTH ELECTRIC COMPANY

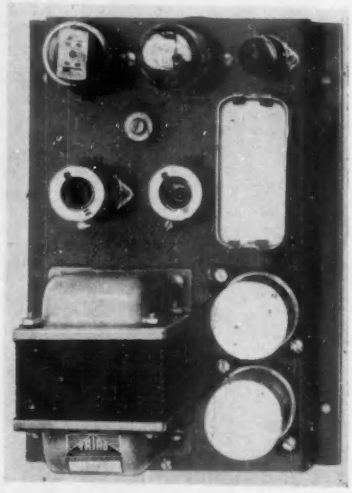
747 SOUTH MARKET STREET • GALION, OHIO

Available in Canada through Ericsson Telephone Sales of Canada, Ltd., Montreal 8, P. Q.

NEW PRODUCTS

0.5 to 100 amp, are provided, with corresponding power ranges up to 12 kw. Prices start at $1,890.—Dayton Electric Mfg. Co., Chicago, Ill.

Circle No. 34 on reply card



DC REFERENCE SUPPLY

Model C25, a compact, electronically regulated dc power supply rated at 300 volts, 0 to 50 ma, is designed as a reference supply for larger equipment. Line and load regulation is within 0.1 percent; ripple is held to 1 mv. Unit measures 8 in. long by 5⅞ in. wide by 4⅛ in. high. It will handle input voltages from 105 to 125 vac at 50 to 60 cps.—Universal Electronics Co., Los Angeles, Calif.

Circle No. 35 on reply card

AIRBORNE POWER

A new airborne dc power supply features three simultaneous outputs rated at: plus 300 vdc at 300 ma; plus 150 vdc at 200 ma; and minus 150 vdc at 200 ma. Unit operates on 208-volt 400-cycle current, and provides line and load regulation within 0.01 percent. Designed to meet MIL-E-5400 specifications for temperature and altitudes, it will also withstand 10-g shocks at 1,000 cps. Unit weighs 68 lb.—Davenport Mfg. Co., Chicago, Ill.

Circle No. 36 on reply card

VOLTAGE-REGULATED

First of a series of new tubeless, magnetic amplifier, voltage-regulated power

speaking of reducing...

new weston pneumatic pressure reducers

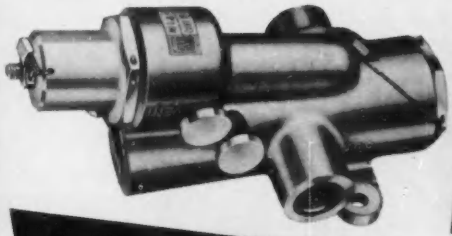
give you up to 1000 scfm at only 1.87 lbs.!

SPECIFICATIONS

Inlet Pressure—3000 psi
Rated Flow—Up to 75 lbs/min. (1000 SCFM)
Outlet Pressure—As required—200 to 2800 psi
Relief Pressure—115% of Outlet Pressure
Maximum Leakage—5 c.c./min standard air
Ports—½ inch tube size
Temperature Range— —65° to 180° F
Overall Dimensions—6.85 x 3.5 x 3.4 inches
Weight—1.87 lbs.

Endurance tested for 100,000 cycles. Integral bleed-down feature releases outlet pressure when inlet pressure is removed.

Weston Reducers feature close control of outlet pressure over a wide range of inlet pressures and outlet flows. Performance exceeds the requirements of specification MIL-R-8572A (Aer.). Designs are presently available with flow capacities up to 2000 SCFM! We invite your solicitation with reference to specific application.



Here's just one example of the many types available!

BW weston
HYDRAULICS, LIMITED
A SUBSIDIARY OF BORG-WARNER CORPORATION
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• 14 South Boro Lane, Glen Rock, New Jersey
• Telephone Gilbert 4-2094

GYROS
for every application

The Kearfott miniature 4 Gimbal 3 Gyro, stable platform, provides precise azimuth, pitch and roll information—irrespective of the airframe attitude. It is hermetically sealed for environmental protection. Because of its rapid warmup characteristic, this unit is fully operational in less than five minutes. This platform provides the features of a magnetic slaved or a latitude corrected directional gyro for heading reference. Dependable, accurate single purpose Kearfott Gyros also available.

ALL ATTITUDE 3 GYRO STABLE PLATFORM

Suitable for use in both missile and aircraft, random drift rate 1° per hour in azimuth and 3° per hour in vertical. Measures only 8" Diam. x 8¾" High, weighs but 23 lbs.

Send for bulletin giving data of components of interest to you.

KEARFOTT COMPONENTS INCLUDE:

Gyros, Servo Motors, Synchros, Servo and Magnetic Amplifiers, Tachometer Generators, Hermetic Rotary Seals, Indicators and other Electrical and Mechanical Components.

KEARFOTT SYSTEMS INCLUDE:

Directional Gyro Compass Systems, 3 Gyro Stable Platform Systems and Inertial Navigational Systems.

Kearfott

A SUBSIDIARY OF GENERAL PRECISION EQUIPMENT CORPORATION

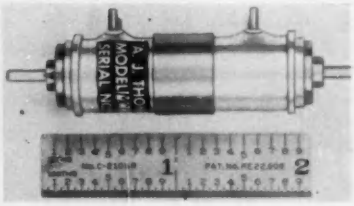
KEARFOTT COMPANY, INC., LITTLE FALLS, N. J.

Sales and Engineering Offices: 1378 Main Avenue, Clifton, N. J.
Midwest Office: 23 W. Calendar Ave., La Grange, Ill. South Central Office: 6211 Denton Drive, Dallas, Texas
West Coast Office: 253 N. Vinedo Avenue, Pasadena, Calif.

supplies, the Model KM236-15 furnishes 2-36 volts, 0-15 amp continuous duty dc. Features include: output voltage variation less than 0.5 percent for line fluctuations between 105 and 125 volts, and less than 0.5 percent or 25 mv, whichever is greater, for load variations from minimum to maximum current; ripple less than 0.5 percent or 25 mv rms; and operation in the frequency range of 57 to 63 cps. Cabinet is 19 in. wide, 17 in. deep, and 12¼ in. high.—Kepco Laboratories, Inc., Flushing, N. Y.

Circle No. 37 on reply card

FINAL CONTROL ELEMENTS



MINIATURE CLUTCHES

Shown is the smallest of four new miniature electromagnetic clutches, all featuring two input gear hubs and one output shaft. Normally both hubs and the output shaft are free running; energizing either coil clutches its respective input hub to the output shaft. Units operate on dc and are well suited for use as speed or direction changers in servo-type applications. Minimum torques range from 3.5 oz-in. to 52 oz-in., while overall dimensions (exclusive of shafts) range from 0.594 in. in diam by 1.978 in. long to 1.370 in. in diam by 3.76 in. long.—Autotronics, Inc., Florissant, Mo.

Circle No. 38 on reply card

PULL-TYPE SOLENOID

A miniature pull-type solenoid for aircraft, missile, and electronic applications, operating on voltages from 6 to 100 vdc, meets the requirements of MIL-S-4040. At 0.3 amp, 100 vdc, and 78 deg F, force is 1.3 lb, with a 0.03-in. stroke. At these same conditions, force is 0.8 lb with a 0.06-in. stroke, and 0.4 lb with a 0.125-in.

INSURING RF SIGNAL RECEPTION AND TRANSMISSION IN THE LOCKHEED X-17 TEST MISSILE

The Rheem REL-09 Miniature RF Power Amplifier has been used in the X-17 test missile since the inception of the project.

The REL-09 provides power amplification over the 215-235 mc telemetering band. With 1.4 watts input drive, it will deliver an 11-watt output to a 52-ohm load. Grid and plate tuning controls are accessible from the front plate. Automatic protection is provided against damage resulting from loss of drive or plate power. Power leads contain 84-db attenuation filters. No cooling or shock mounting is required.

For further information, write direct to Rheem or contact your area sales representative:

North Central
Sam Robbins, Inc.
230 East 1st Street, Flint 2, Michigan

Florida
Arthur H. Lynch & Associates
P.O. Box 466, Fort Myers, Florida

New England and New York State
Electronics Associates, Inc.
200 5th Street, Stamford, Conn.

Central East Coast
F. R. Jodon, Inc.
8510 Beech Tree Road, Washington 14, D.C.

Southwest, Rockies and State of Washington
George E. Harris & Co., Inc.
3241 East Douglas, Wichita 8, Kansas

THE LOCKHEED X-17 TEST MISSILE
The X-17 provides information on the problems which arise when the warhead of a ballistic missile re-enters the earth's atmosphere at high speed.

ELECTRONICS DIVISION
RHEEM MANUFACTURING COMPANY

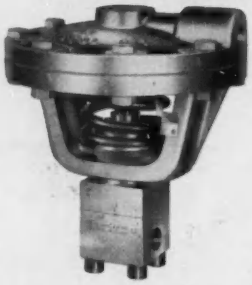
Rheem

7777 Industry Avenue, Rivera, California

8-57

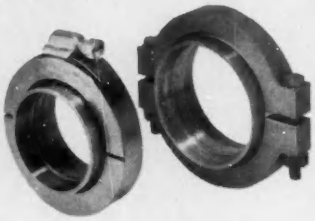
MINIATURIZATION

From Pilot Plant to Process



♦ "BANTAM" 500 SERIES

Throttling "Bantam" Diaphragm Control Valves for all standard control valve uses, Cv of 0.6 and below, up to 1000 psi and 500°F, characterized, renewable trim, 316 stainless steel and teflon only wetted surfaces, low in hysteresis, size and weight, a modern design of control valve. 2000 series "Bantam" Control Valves available for on-off service.

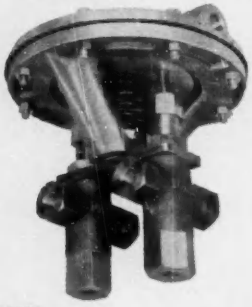


TUBE AND PIPE CONNECTORS ♦

For use in such systems as aircraft or marine applications where weight is a factor, these connectors replace standard flanges. Available in various materials, in male or female socket or butt weld design, for tubing, and up to schedule 40 pipe.

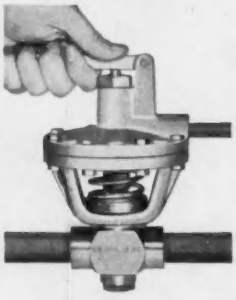
♦ "DEMI" PACKLESS VALVES

For services when packing is a problem, manifolding of small valves in one unit, these low cost valves have a great popularity. For services up to 1500 psi and 500°F., screw, toggle, or diaphragm operated, the "Demi" line is ideal for panel mounting up to five valves in one block.



WHIFFLETREE OPERATOR ♦

Two valves operated simultaneously by one operator. Valves may be globe or three-way and have a multitude of piping arrangements for mixing and routing applications.



♦ MANUAL RESET

Wherever control air on dangerous or toxic process flows must be blocked for safety, on air failure until manually reset, these valves insure against disaster. Standard sizes ¼" and ½" I.P.S.

SAUNDERS VALVES — AIR OPERATED ♦

Plastic valves, 2" and below, metal valves 1" and below, G. W. Dahl Company, Inc. diaphragm operators on these valves provide simple, sure automatic operation. Each application must submit full flow information.

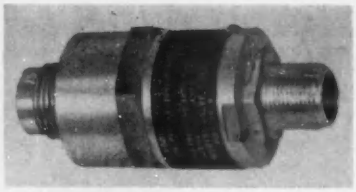
Write us for complete technical information, or the address of our representative in your area.

George W. DAHL Company

BRISTOL, RHODE ISLAND

stroke. Operating temperature range is minus 65 to plus 100 deg F.—Carruthers & Fernandez, Inc., Santa Monica, Calif.

Circle No. 39 on reply card



TAKES PRESSURE TO 4,500 PSI

This three-way, normally-open, magnetically operated pilot valve weighs only 0.375 lb, yet is rated for up to 4,500 psi service. An hermetically sealed solenoid operating within a 14-to-32-volt range controls the flow through what is equivalent to a 0.030-in. sharp edge orifice. Used mainly for piloting larger valves, this rugged miniature boasts an ambient temperature range of minus 100 to plus 250 deg F.—Marotta Valve Corp., Boonton, N. J.

Circle No. 40 on reply card

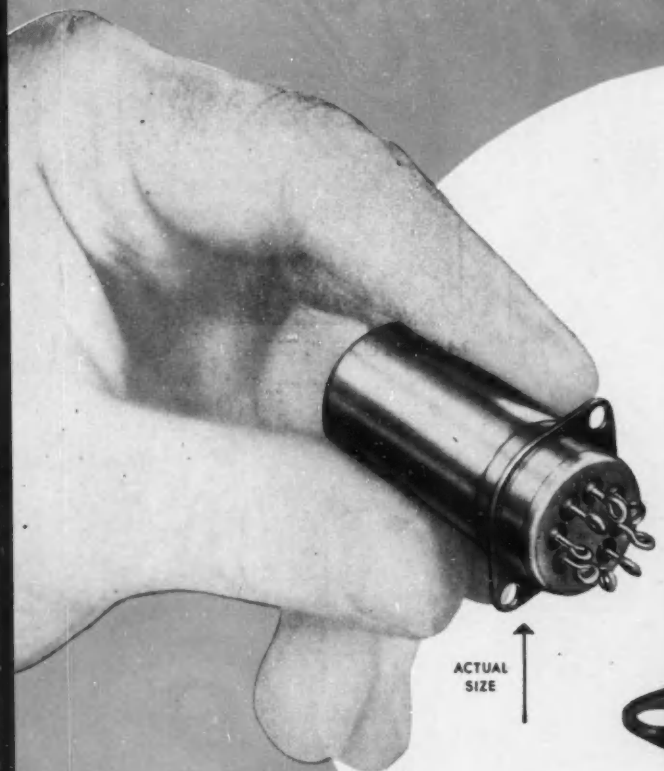
COMPONENT PARTS

PRECISION GEARHEADS

The Model 1384-GH, shown here, is one of four new motor gearhead adaptations designed for size 11 motors. All, now in production, are 1.062 in. in diam. The 1384-GH is offered for heavy-duty installations requiring short length at standard ratios. Model X-295 features an off-center shaft and ratios to 1,000:1. Tandem design in the X-507 model provides ratios to 3,000,000:1 and higher while maintaining low backlash. A fourth model, the X-414, contains internal stops to limit rotation, and a slip clutch to

New 3/4" Sensitive Relay

APPLICABLE TO PRINTED CIRCUITS



ALLIED TYPE RSH has sensitivity of 40 milliwatts in D.P.D.T. and 22 milliwatts in S.P.D.T.

ELECTRICAL SPECIFICATIONS

CONTACTS: Up to D.P.D.T. rated at 2 amperes at 26.5 volts DC or 115 volts AC resistive load

COIL: Sensitivity—40 milliwatts D.P.D.T.
22 milliwatts S.P.D.T.
Resistance—up to 14,000 ohms

TEMPERATURE: Minus 60° C to plus 125° C

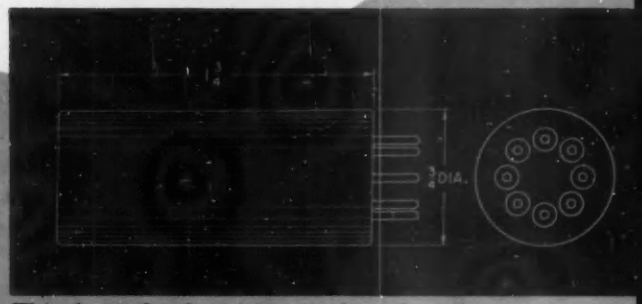
VIBRATION: 10G up to 500 cycles

SHOCK: 50G plus (operating)

ALTITUDE: 70,000 feet or 1.3 inches of mercury

TERMINAL TYPE: Solder, plug-in, and printed circuit.

WEIGHT: 2 ounces

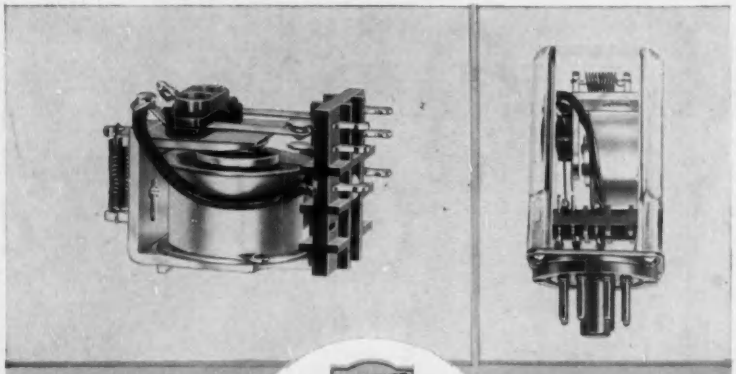


Write for catalog sheet giving complete information

ALLIED CONTROL

ALLIED CONTROL COMPANY, INC., 2 EAST END AVENUE, NEW YORK 21, N.Y.

AL 186



ELGIN
announces the
NEW ADVANCE
GH
SERIES
Low Cost
Midget Relays
. . . open or plastic enclosed

Elgin's new GH series combines the high efficiency required of general purpose relays with low cost. Their midget size suits them for installations where space is a problem (see specifications below). Open relays in 5 and 10 ampere ratings and clear plastic dust-tight enclosed 5 ampere relays are immediately available from stock. Specify dependable ELGIN performance . . . specify GH from your electronic parts distributor!

SPECIFICATIONS

GHA SERIES, 5 amp. open relay

Contact rating, 5 amps. resistive, 2 amps. inductive at 115 volts AC or 26.5 volts DC. Contact material is fine silver, 1C,2C,3C arrangements only. Relay is 1.1" high, 1.732" long and .937" wide. Contact terminals can be used as solder lugs or for printed circuitry.

(Also available: GHB series, 10 amp. open relay.)

GHP SERIES, 5 amp. clear plastic enclosed relay.

Dust-tight plug-in. Contact rating, 5 amps. resistive, 2 amps. inductive at 115 volts AC or 26.5 volts DC. Contact material is fine silver, available in 1C or 2C arrangements only. Enclosure is $2\frac{11}{16}$" x $1\frac{13}{32}$" overall. $2\frac{1}{8}$" overall length above chassis.

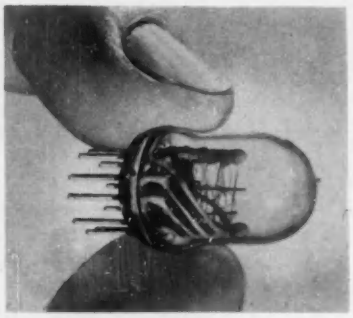
NOMINAL POWER REQ.—DC relays, 1 to 2 watts; AC relays, 2 to 3 volt amperes.
NOMINAL VOLTAGE—DC relays, 6 to 120 volts; AC relays, 6 to 220 volts. (On specification, DC voltage coil up to 220 volts or AC voltage coil up to 440 volts can be supplied.)
RESISTANCE — DC relays, 25 to 8,000 ohms; AC relays, 4 to 5,000 ohms.
PULL-IN CURRENT VALUES—7.2 Milliamps max. at 2,500 ohms; 5.0 milliamps max. at 5,000 ohms.
DUTY CYCLE—continuous.
TEMPERATURE RANGE— $-55°$ to $+85°$C when specified.
INSULATION RESISTANCE — 100 megohms min.
DIELECTRIC STRENGTH — standard: 500 volts RMS. (When specified, 1,000 volts RMS can be met.)
MAXIMUM WEIGHT—2 ounces.

ELECTRONICS DIVISION
ELGIN NATIONAL WATCH COMPANY
2435 N. Naomi Street, Burbank, California

NEW PRODUCTS

prevent motor or gearhead damage.—Bowmar Instrument Corp., Fort Wayne, Ind.

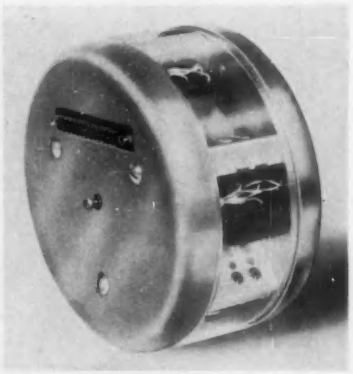
Circle No. 41 on reply card



MINIATURE "NIXIE"

Shown is a new gas-filled, cold cathode, 10-digit numerical indicator tube for direct in-line readout devices. Four times smaller than the standard Nixie, it measures 0.6 in. in diam by 0.75 in. high and is said to be clearly visible at 10 ft. It uses about 40 percent less voltage than the standard size and operates at about ¼ the wattage. Applications include aircraft instrument panels, computers, industrial controls, counters, meters, and indicators.—Electronic Tube Div., Burroughs Corp., Plainfield, N. J.

Circle No. 42 on reply card



MEMORY DRUM

More than 12,000 bits of data and associated clock and reference information can be stored in this new miniaturized magnetic memory drum. Manufacturer claims it is suitable for data handling, computer systems, and laboratory testing. Standard drum is $3\frac{1}{2}$ in. in diam and contains 12 in-

FOUR NEW G-E Silicon TRANSISTORS

TYPES
4JD4A2
4JD4A3
4JD4A4
4JD4A5

- *Operation below zero and up to 150°C*
- *25 mc alpha cutoff*
- *Low leakage current*
- *Easy automatic insertion in printed circuit board*

DESIGN FEATURES

High Temperature Performance . . . maximum ambient operating temperature 150° C, storage temperature up to 200° C

New Package Design . . . for automatic insertion in printed circuit boards

Package Hermetically Sealed . . . no moisture seepage from outside air

Package Seams Are Welded . . . for great strength, long wear

Long Life and Stable Performance . . . when used within specified ratings

Small Size . . . extremely compact design provides added flexibility for most applications

Here are just a few typical applications for the NPN silicon triode transistors: wide band and d-c amplifiers, oscillator circuits, computer switching.

And now *all* General Electric transistors are a better buy than ever. Because of mechanized production lines, G-E transistors are made in less time and at a lower cost than before. Thus you benefit from lower prices.

Besides, machine methods used on the General Electric production lines promote the strictest adherence to top quality standards. As a result, characteristics are controlled and narrow limits are built into the production transistor for a more uniform product. Therefore, General Electric is able to give a one-year written warranty.

For specifications and application engineering assistance, call your G-E Semiconductor District Sales Manager, your G-E Semiconductor distributor, or write the General Electric Company, Semiconductor Products, Section S-1677, Electronics Park, Syracuse, N. Y.

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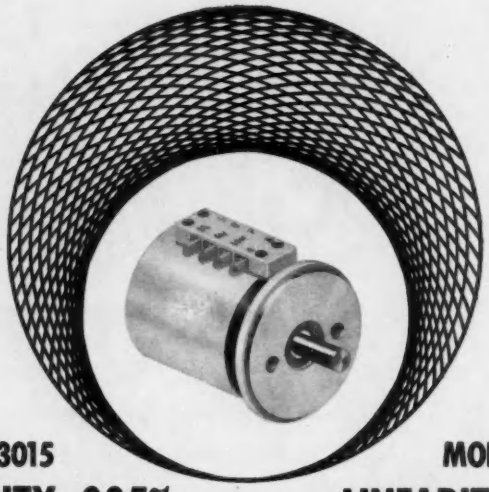
ECG-226



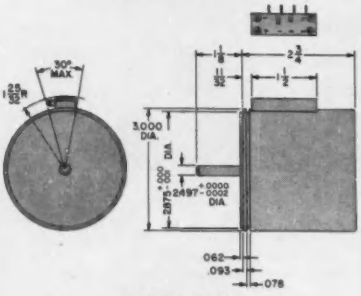
MODEL J3015
LINEARITY .005%

MODEL F1810
LINEARITY .01%

HIGH PRECISION POTENTIOMETERS

IMMEDIATELY AVAILABLE IN PRODUCTION QUANTITIES
SAMPLES SHIPPED IN 48 HOURS

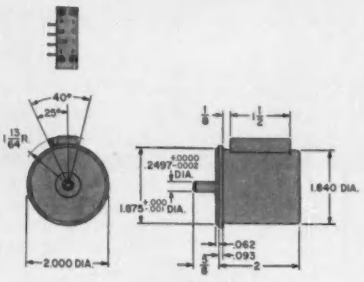
15 TURN – 3 IN. DIA.



MODEL J3015

RESISTANCE RANGE	2K TO 150 K
LINEARITY (STANDARD)	.05% TO .01%
LINEARITY (BEST)	.005% ABOVE 4 K

10 TURN – 1.8 IN. DIA.



MODEL F1810

RESISTANCE RANGE	1 K TO 50 K
LINEARITY (STANDARD)	.05% TO .02%
LINEARITY (BEST)	.01% ABOVE 2K

Now you can design your circuits with Analogue Controls Potentiometers with the assurance that they will be available when you need them!

Complete mechanical and electrical specifications of all our potentiometers are available. Write for Catalog P103 today.

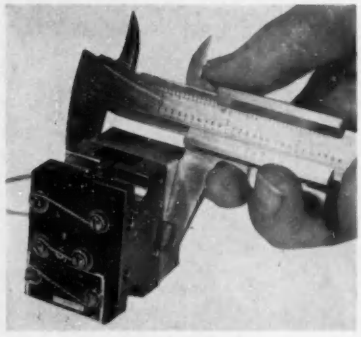
POTENTIOMETERS MEET THE REQUIREMENTS OF NAS-710

Analogue Controls, Inc.
39 ROSELLE STREET, MINEOLA, NEW YORK
PIONEER 2-8901

NEW PRODUCTS

formation channels plus clock and fiducial channels. Belt-driven drum has variable speeds to 15,000 rpm. Access time is about 1.25 millisec.–BJ Electronics, Borg-Warner Corp., Santa Ana, Calif.

Circle No. 43 on reply card



NEW TORQUEMOTOR

This compact torquemotor, designed primarily to stroke the flow-controlling element in hydraulic or pneumatic servo-valves, is being used in a number of applications as a basic transducer to convert a few watts of input power into a linear mechanical motion with forces up to 7.5 lb. Coils are completely impregnated and encapsulated to accommodate immersion or high-humidity environments. Some of its physical characteristics: size, 2.25 in. by 1.30 in. by 1.72 in.; weight, 14 oz; output radius, 0.750 in.; moment of inertia, 27 microin.-lb-sec^2; and maximum ambient temperature, 150 deg C.–Midwestern Instruments, Tulsa, Okla.

Circle No. 44 on reply card

NEW TACHOMETERS

This company is now offering a new line of motor tachometers and tachometer generators for high-accuracy computers and servo systems used in missile, navigation, fire control, and similar applications. These units feature 0.12 percent linearity from 0 to 4,000 rpm, temperature compensation to plus or minus 0.3 percent over an operating temperature range of minus 55 to plus 80 deg C, and pretrimmed output voltage. The tachometer generators can be combined with a wide choice of size 15 and 18 low-inertia servomotors.–Norden-Ketay Corp., Stamford, Conn.

Circle No. 45 on reply card

Servo Motors For

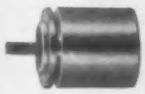
Transistorized Operations

• Meets MIL-E-5272 • −65°C to +125°C temperature range.

Oster

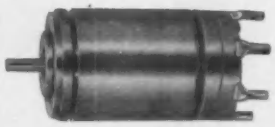
	SIZE 8	SIZE 10	SIZE 11	SIZE 15	SIZE 18
Oster Type	8-5001-00	10-5052-00	11-5101-00	15-5153-00	18-5201-00
Electrical Characteristics:					
Frequency (cps)	400	400	400	400	400
Torque at Stall (oz. in.)	.15	.30	.63	1.45	2.35
No Load Speed (rpm)	6500	6500	6500	5200	5200
Speed at Half Torque (rpm)	4000	4000	4000	3200	3200
Time Constant (sec.)	0.03	0.015	0.016	0.017	0.013
Reversing Time (sec.)	0.051	0.025	0.028	0.030	0.022
Theo. Acceleration at Stall (rad/sec²)	22500	45000	41500	31000	40000
Operating Temp. Range (°C.)	−54 to +125	−54 to +125	−54 to +125	−54 to +125	−54 to +125
Slot Effect	1.6v/26v	1.0v/36v	1.0v/40v	1.0v/40v	1.0v/40v
Duty Cycle	Cont.	Cont.	Cont.	Cont.	Cont.
Fixed Phase					
Voltage	26	115	115	115	115
R (Stall) Ohms	196	1270	1250	490	280
X (Stall) Ohms	183	1560	1780	890	570
Z (Stall) Ohms	268	2210	2175	1030	640
P.F. (Stall)	0.73	0.57	0.58	0.49	0.45
Effective R (Stall) Ohms	366	3840	3800	2160	1460
Parallel Tuning cond. for unity P.F. (Stall) Mfd.	1.0	0.13	0.15	0.33	0.55
Control Phase					
Voltage	40/20	40/20	40/20	40/20	40/20
*R (Stall) Ohms	480	124	145	58	39
*X (Stall) Ohms	445	215	204	103	77
*Z (Stall) Ohms	660	248	250	118	86
*P.F. (Stall)	0.73	0.50	0.58	0.49	0.45
*Effective R (Stall) Ohms	910	495	430	240	190
*Parallel Tuning cond. for unity P.F. (Stall) Mfd.	0.4	1.4	1.3	2.9	4.1
Mechanical Characteristics:					
Rotor Inertia (gm. cm²)	.47	.47	1.07	3.3	4.0
Weight (oz.)	1.2	2	4.5	8	14
Mounting Type	Synchro	Synchro	Synchro	Synchro	Synchro
Motor Length	.863	.672	1.703	1.625	2.03
Type Shaft	Pinion	Pinion	Plain	Plain	Plain
Shaft Extension	.375	.218	.437	.540	.540
Outside Diameter	.750	.937	1.062	1.437	1.750
Type Connection	Leads	Terminals	Terminals	Terminals	Terminals

*For 40v connection



Size 8

Size 10



Size 11

Size 15

Size 18

This complete line can be varied by Oster specialists to your precise requirement. Write today for further information, enclosing detailed data on your needs.

Other products include motor-gear-trains, synchros, AC drive motors, DC motors, servo mechanism assemblies, motor tachs, servo torque units, reference and tachometer generators, actuators, motor driven blower and fan assemblies and fast response resolvers.

John Oster

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$700.00 f.o.b. Los Angeles

Statham MODEL TC-4 TEMPERATURE TEST CHAMBER

The Statham Model TC-4 portable Temperature Test Chamber has proven its versatility and value for years in such fields as the Aircraft, Electrical, Electronic, Automotive, and Chemical industries. Its wide operating range—from −75°F to +600°F makes this unit the ideal solution for ambient temperature tests in the *Laboratory* or on the *Production Line*. Accurate and adjustable control, wide temperature range, and a product capacity of 600 cubic inches provide the most versatile test chamber available for your testing needs. Interchangeable extra trays may be ordered for greater convenience and elimination of loading delays.

Write for descriptive literature on this and other models, or wire or call for prompt reply on your application.

Statham DEVELOPMENT CORPORATION
12411 West Olympic Boulevard, Los Angeles 64, California
GRanite 7-9157.

NEW PRODUCTS

SILICON TRANSISTORS

Fifteen new silicon transistors, in round welded cases, are designed and built for automatic production systems and military applications. Two of the new models are switching transistors with total switching times down to 100 millimicrosec. Both are n-p-n grown-diffused types, featuring high alpha cutoff frequencies and low collector capacities. Other models: three high frequency tetrodes, five medium power devices, and five small signal transistors.—Texas Instruments, Inc., Dallas, Tex.

Circle No. 46 on reply card

MISSILE GYRO

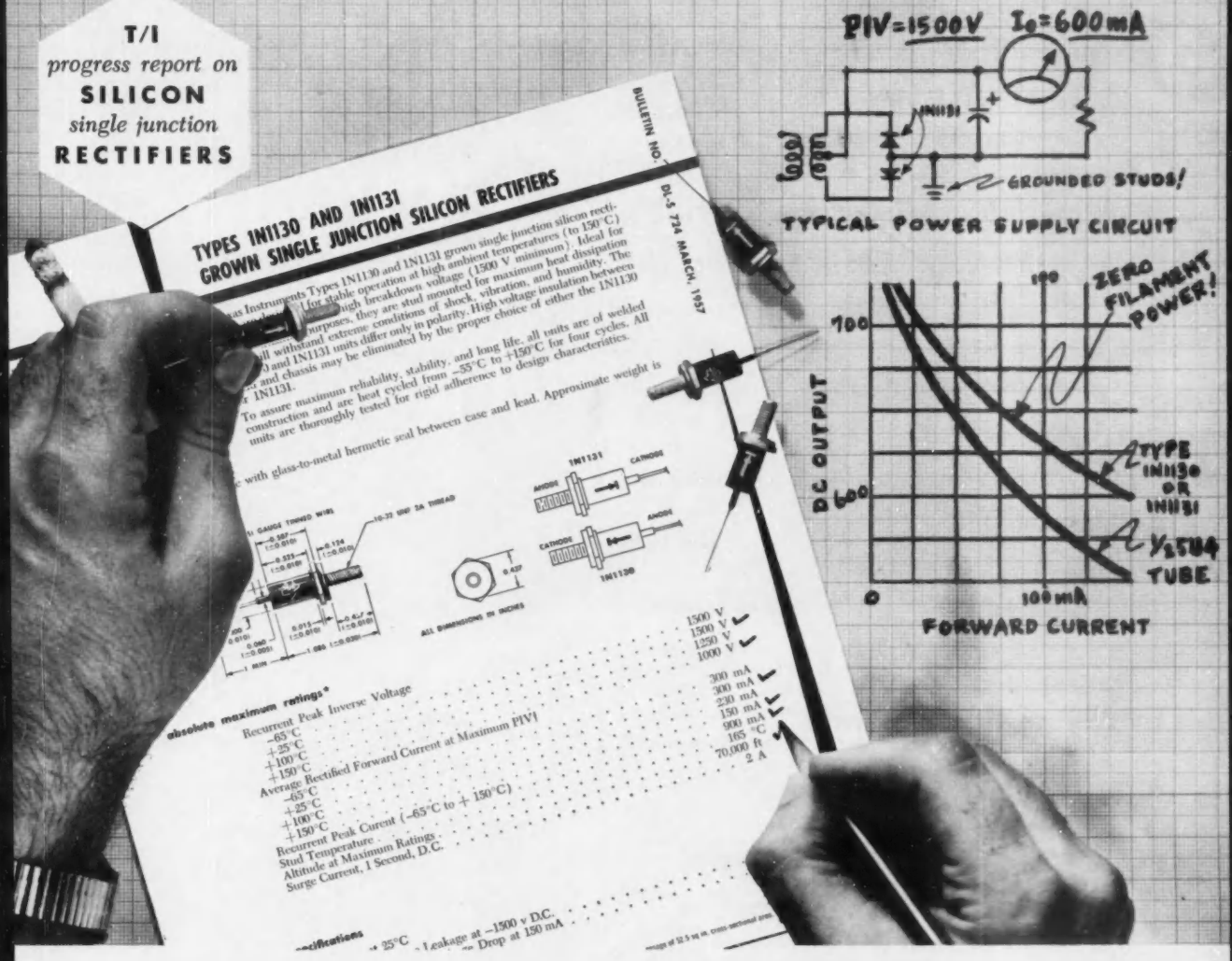
Model 55,000 Floated Rate Gyro, designed to meet the rugged vibration conditions encountered by missiles, is said to maintain an accuracy within plus or minus 0.5 percent. Maximum rate ranges of from 1 deg to 1,000 deg per sec are available. Use of an inductive signal pickoff provides a higher power signal output than previously available in this size, and damping ratio can be made to suit customer requirements and maintained within 0.1 over the temperature range of minus 55 to plus 85 deg C.—Norden-Ketay Corp., Stamford, Conn.

Circle No. 47 on reply card

HIGH DC OUTPUT

A newly designed permanent-magnet dc generator, 1.25 in. in diam by 2.6 in. long, has a 10-watt output at 8,000 rpm. At this speed, it has a 1,000-hr

T/I
progress report on
SILICON
single junction
RECTIFIERS



new design freedom for your miniature high voltage power supplies with . . .

NEW TI 1500 V, 300 mA RECTIFIERS

You can replace 5R4 and 5U4 rectifiers with TI's new single junction rectifiers in many applications. In a fraction of the space, you will get instant operation at high temperatures with *zero filament power*. Here are some significant ratings of these new Texas Instruments Types 1N1130 and 1N1131 (differing only in polarity):

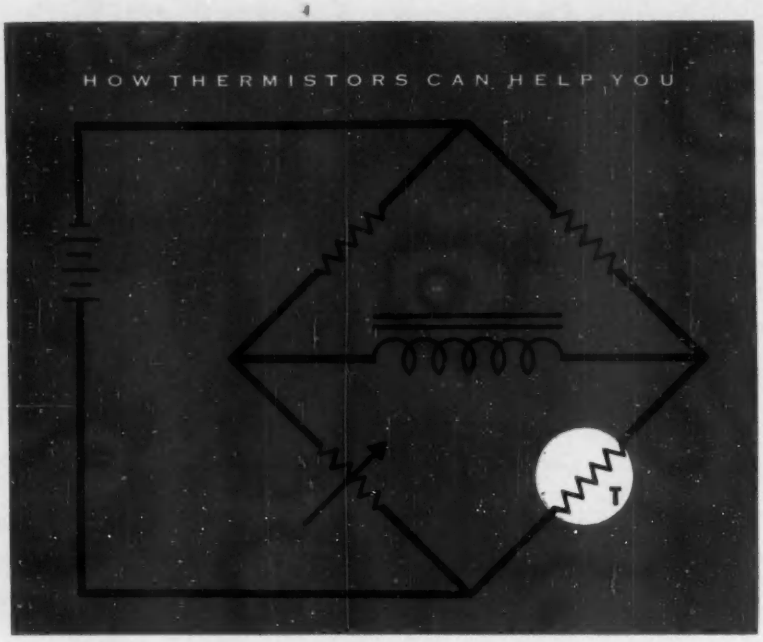
VALUE	AMBIENT TEMPERATURE	
	25°C	150°C
PIV	1500 V	1000 V
I_f (at max. PIV with heat sink)	300 mA	150 mA

Designed to meet stringent military requirements, these TI rectifiers give you the ultimate in hermetic seal protection. The standard RETMA stud is of *copper* for optimum performance and the hex base assures high-torque chassis mounting. High voltage insulation between stud and chassis can be *eliminated* by proper choice of either 1N1130 or 1N1131.

400 V, 750 mA TI TYPE 1N540
ECONOMICAL *diffused* RECTIFIER
***lower* FORWARD VOLTAGE DROP**

Reliability of your power supplies is assured by this rectifier . . . giving you cooler operation. Typically, at 150° C, they give you 0.64 V voltage drop at 250 mA and 0.20 mA reverse current at 250 V.

TEXAS INSTRUMENTS
INCORPORATED
6000 LEMMON AVENUE DALLAS 9, TEXAS

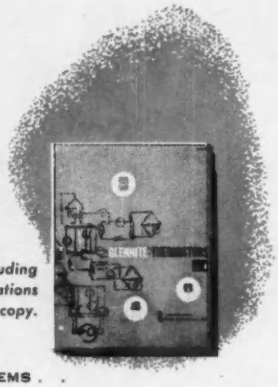


Designing Temperature Alarms with GLENNITE® Thermistors

Temperature alarm design problems can be solved economically and efficiently in many cases with Glennite® Bead Thermistors.

Using a bead thermistor in the bridge circuit illustrated provides a simple yet precise alarm system. Any slight change in temperature over the range of −60° C to +400° C causes a relatively large resistance change in the thermistor. This change in resistance is used to activate the relay.

Temperature monitoring is but one of the many uses for versatile Glennite® Thermistors which are available in a wide variety of configurations to satisfy individual requirements.



Brochure T-100 gives full details including design data and specific applications write for your copy.

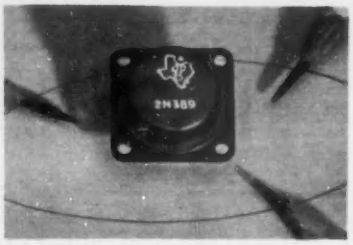
FROM RAW MATERIALS TO COMPLETE SYSTEMS

Thermistor Division
Gulton Industries, Inc.
METUCHEN, NEW JERSEY

NEW PRODUCTS

life and a maximum temperature rise of 25 deg C. Unit has a 3 oz-in. input torque; its weight is 7 oz.—John Oster Mfg. Co., Avionics Div., Racine, Wis.

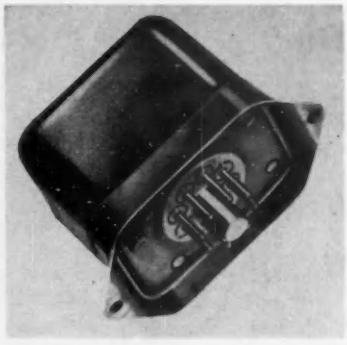
Circle No. 48 on reply card



15 WATTS AT 100 DEG C

Pictured is the first commercially available gaseous diffused-junction transistor. The unit features a rated power dissipation of 37.5 watts at 25 deg C and 15 watts at 100 deg C. With a 2-amp collector current, it has a maximum saturation resistance of only 6 ohms. In aircraft applications, a 60-volt collector-to-emitter rating allows power to be taken directly from the 28-volt power supplies. Operating temperature range is minus 65 to plus 150 deg C.—Texas Instruments, Inc., Dallas, Tex.

Circle No. 49 on reply card



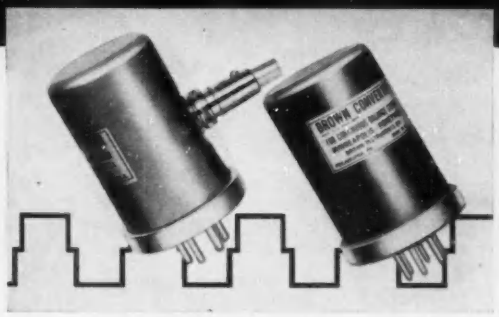
60-CYCLE CHOPPER

This new 60-cycle "Microverter" chopper can be used to convert a low-level dc signal, e.g., 10 mv (such as produced by thermocouples and photocells) into a low-level ac signal which may then be amplified to operate various controls in null balance servo systems, industrial instruments, etc. Stability under shock and vibration is

Use high-quality, dependable

BROWN COMPONENTS

in your measuring circuits and servo loops

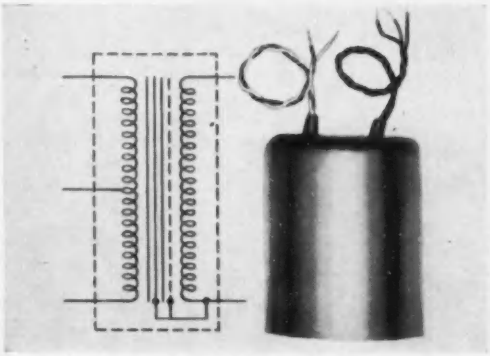


CONVERTERS—Handle d-c signals as small as 10^{-8} volt. SPDT switching action. Sensitive, stable performance. Ideal for computers, servomechanisms, balancing circuits. Available with special features such as fungus proofing, grounded housing, mica-filled base, various contact percentages. Weight: 10 ounces.

Driving coils in 60, 40 and 25 cycle converters are energized by 6.3 volt a-c. 400 cycle uses 18 volts. Other coil ratings as follows:

Converter Type	Impedance	D-C Resistance	Power Consumption	Current Drain
60 cycle	125 ohm	110 ohm	.3 watts	.05 amps
25 and 40 cycle types	65 ohm	55 ohm	.60 watts	.10 amps
400 cycle	191 ohm	110 ohm	1.7 watts	.094 amps

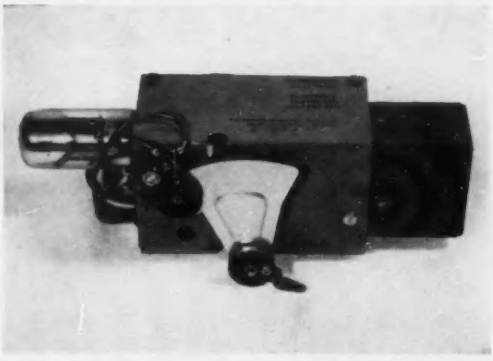
Write for Specification S900-2.



INPUT TRANSFORMERS—Handle low-frequency a-c, or chopper-modulated d-c signals from .005 to 200 millivolts, such as generated by thermocouples or other transducers. Designed with highly efficient shielding. Measure 1⅝" in diameter, 2½" high.

Choose from three models		355567-1	356326	35567-2
Primary (center-tapped)	turns (½ primary)	600	1,094	3,400
	Resistance (approx.)	30 ohms	450 ohms	750 ohms
	60 cps impedance	1,300 ohms	7,500 ohms	30,000 ohms
	Impedance, full pri.	5,200 ohms	30,000 ohms	120,000 ohms
Secondary	turns	9,600	17,500	12,000
	Resistance (approx.)	2,500 ohms	5,800 ohms	3,400 ohms
	Capacity to tune to 60 cycles	.015 mfd.	.001 mfd.	.003 mfd.
Weight		5.7 oz.	7.1 oz.	6 oz.

Write for Specification S900-1.



***ELECTR-O-VANE* CONTROL UNIT**—A torque of 2 gram-inches or less actuates this precision switch. Use it as a limit switch to operate valves, lights or hopper openings, in response to motion of weighing beams or other members. Use it to sense other mechanical movements—to operate protective devices when a diaphragm is bulged or near rupture, for example.

SPECIFICATIONS

Torque to move vane . 2 gram-inches max.
Vane motion for snap action . . 0.003 in.
Precision . . . . . within 0.002 in.
Switch action . SPDT, when vane centerline approx. 41° left of vertical
Load relay rating . 115 volts, 6 amp. a-c, non-inductive load
Operating power . 115 volts, 50-60 cycles; also 230 volt model

Write for Specification S800-1.

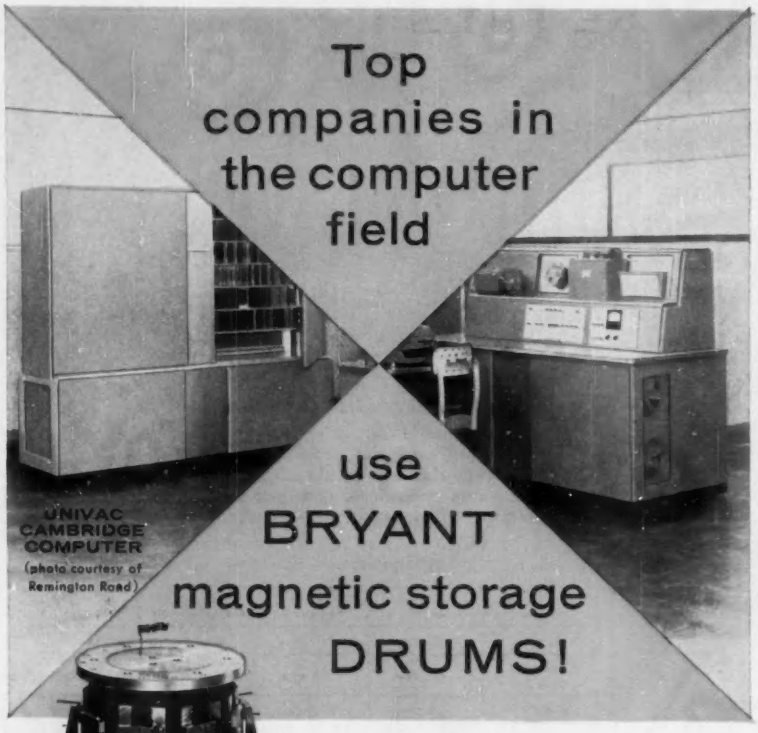
For additional details, call your nearby Honeywell sales engineer. He's as near as your phone.

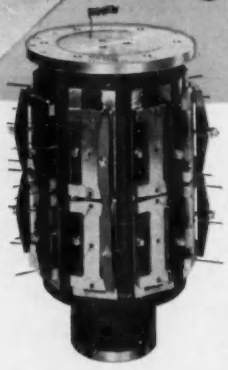
MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

Honeywell

H HONEYWELL

First in Controls


Top companies in the computer field
use BRYANT magnetic storage DRUMS!
UNIVAC CAMBRIDGE COMPUTER
(photo courtesy of Remington Rand)



Bryant Magnetic Drums are used extensively by Remington Rand—Univac and other leading manufacturers of electronic computers, because of their accurate, dependable performance. These drums are used not only in digital computers, inventory control systems and tape-to-card converters, but also as delay lines, synchronizers and frequency generators.

FEATURES

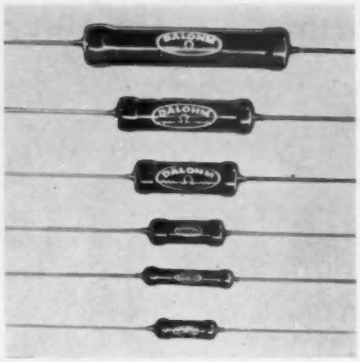
- Designed to purchasers' requirements
- Guaranteed accuracy of drum runout .00010" T. I. R. or less
- Air bearings or super-precision ball bearings
- Belt drive or integral motor drive, speeds to 100,000 RPM or more
- Capacities to 5,000,000 or more binary digits
- Vertical or horizontal housing
- Head mounting surfaces to suit
- High density magnetic oxide coating

BRYANT GAGE and SPINDLE DIVISION
P. O. Box 620-L, Springfield, Vermont, U. S. A.
DIVISION OF BRYANT CHUCKING GRINDER CO.

NEW PRODUCTS

said to be excellent. Unit has a service life of 10,000 hrs at a contact load of 1 ma at 1 vdc resistive. Standard coils with dc resistances from 13 to 7,950 ohms are available for a driving voltage range from 0.5 to 12 volts rms.—Barber-Colman Co., Rockford, Ill.

Circle No. 50 on reply card



POWER RESISTORS

These new, completely noninductive wirewound power resistors are silicone sealed for maximum protection against salt-laden air and humidity. Welded construction provides exceptional unit strength. Available in five wattages, 2, 3, 5, 7, and 10, and six physical sizes, the resistors can meet the most demanding requirements. Maximum continuous operating temperature is 275 deg C. Resistance range is 1 to 37,000 ohms, depending on size and tolerance. Available tolerances range from 0.05 to 3.0 percent.—Dale Products, Inc., Columbus, Neb.

Circle No. 51 on reply card

ACCESSORIES & MATERIALS

HOOKUP WIRE

Some outstanding features of a brand new, thin-wall, insulated hookup wire include: 25 percent lower initial cost, lower contact resistance when penetrating terminals are used, less humidity sensitivity, more effective inspection, and greater conductivity for the same overall wire diameter. Wire was primarily designed for use on electrical business machines. — Rome Cable Corp,. Rome, N. Y.

Circle No. 52 on reply card

FORD BUILDS FOR THE FUTURE WITH

CYPAK

... controlling form grinder sequencing in automatic transmission production

CYPAK* static controls have already outlasted conventional relays previously used at the Ford plant in Livonia, Michigan. No down time for control maintenance has been necessary with this highly repetitive operation in over 17 months!

Logic and sequencing control of two Springfield Machine Tool Co. form grinders is performed by CYPAK static control apparatus. CYPAK activates the solenoids of hydraulic valves controlling the grinder's feed cycle.

In machining the impeller housing of automatic transmissions, the operator places the workpiece in the chuck, presses the cycle button ... and CYPAK does the rest ... automatically.

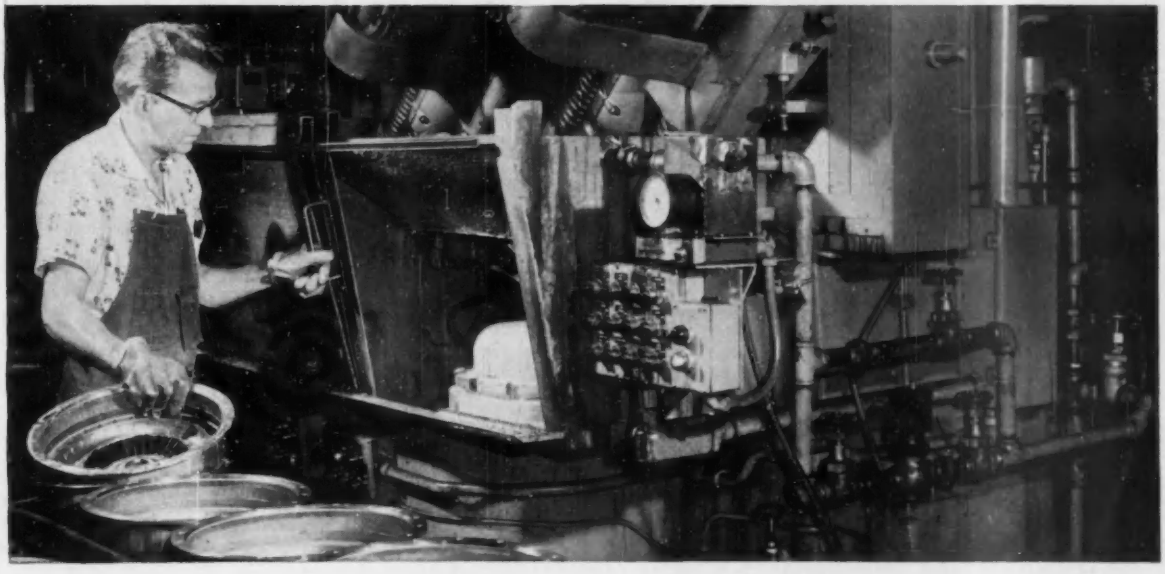
For complete information about CYPAK call your Westinghouse representative, or write Westinghouse Electric Corp., Dept. B, P.O. Box 868, Pittsburgh 30, Pa.

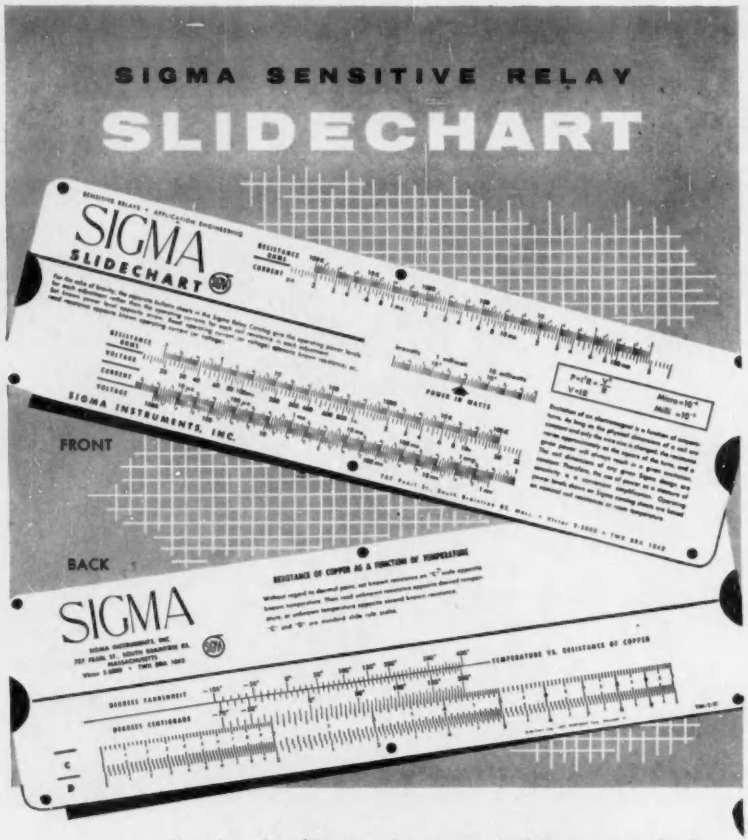
*Trade-Mark

J-22019

YOU CAN BE SURE... IF IT'S

Westinghouse





For the sake of brevity, the separate bulletin sheets in the Sigma Relay Catalog give only the operating power levels for each adjustment (and not the operating currents for *each* coil resistance in *each* adjustment). There were complaints. In this case, brevity was the sole of nitwits. Customers were suffering from Ohm's Law Exhaustion just to buy one relay; so the problem was to devise a device devised to provide a fast, correct answer. And there you have it pictured above, at slightly less than half actual size.

That took care of the front. On the reverse side miscellaneous information and scales were placed, which are not usually found together. This—we divined—would make the SC attractive to you who never lost a second's sleep over what the operating current of a Sigma relay is; would get our name on your desk—and let us charge off a fair chunk of the cost to advertising.

For a limited time only, you can get a Slidechart free if you will ask for it *on your company letterhead*. We reserve the right to sell them at some later date.

You don't need a company letterhead (or even a job) to get a reprint of our current directory advertisement which seems to be a handy guide for those who wonder what we make in terms of what they need. Just ask for EBG* reprint.

* Electronics' Bar & Grill

SIGMA INSTRUMENTS, INC.
69 Pearl Street, So. Braintree 85, Mass.

NEW PRODUCTS

NO DRAG OR BACKLASH

A new poleshoe and hub assembly equips this company's miniature electromagnetic clutches and brakes for "zero drag" release and zero backlash applications. The new poleshoe retains the design feature that permits up to 3 deg of angular misalignment without binding or loss of power. Series 100 units, with the new assembly, are $\frac{11}{16}$ in. in diam by 2 in. long. Series 130 models measure $1\frac{5}{16}$ in. in diam by $2\frac{3}{4}$ in. long. The smaller size delivers over 3 in.-lb. of torque; the larger units, 7 in.-lb. Maximum power consumption is 3 watts.—Dial Products Co., Bayonne, N. J.

Circle No. 53 on reply card

PRECISION BELLOWS

Welded bellows are now available with wall sections as thin as 0.002 in. These extremely flexible bellows are made in any weldable metal on automatic machinery. The model shown, approximately $\frac{3}{4}$ in. in diam by $\frac{1}{2}$ in. long, has a spring constant lower than 7 lb per in.—The Belfab Corp., Agawam, Mass.

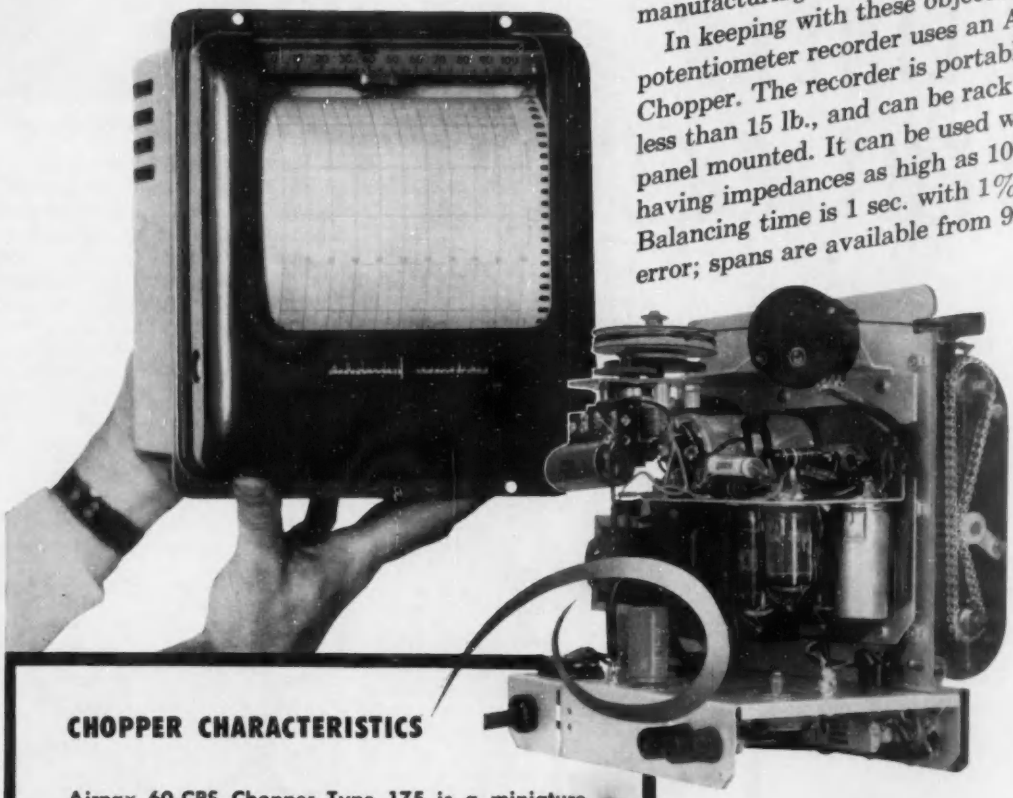
Circle No. 54 on reply card

Compact Low-Cost Recorder uses AIRPAX CHOPPER

New Recorder has Mechanical Modulator

To be certain that their new strip-chart recorder would be easy to maintain in the field, Varian Associates, Palo Alto, California engineered it around a mechanical-chopper amplifier. This design plus precision tooling assured a quality instrument yet reduced the cost of manufacturing it in quantity.

In keeping with these objectives the potentiometer recorder uses an Airpax Chopper. The recorder is portable, weighing less than 15 lb., and can be rack or panel mounted. It can be used with sources having impedances as high as 100 K. Balancing time is 1 sec. with 1% limit of error; spans are available from 9 to 100 mv.



CHOPPER CHARACTERISTICS

Airpax 60-CPS Chopper Type 175 is a miniature unit with permanently adjusted SPDT BBM contacts. Type 800 is similar with DPDT contacts

DRIVE

Frequency	60 CPS
Voltage	6.3 RMS volts

CONTACTS

Dwell Time	167 electrical degrees
Balance	within 15 elec. deg.
Phase Angle	20 elect. deg. lagging
Voltage	up to 100 DC volts
Current	up to 2 milliamperes
Noise	50 microvolts average

Hermetically sealed for trouble-free operation in any atmosphere, internal mechanism rigidly mounted to withstand shock and vibration encountered in portable equipment.

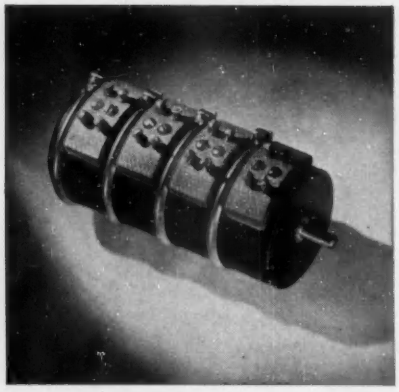
For additional data about choppers and chopper applications in your equipment write to—

DESIGNERS AIRPAX PRODUCTS COMPANY ENGINEERS

CAMBRIDGE DIVISION
JACKTOWN RD., CAMBRIDGE, MARYLAND

Ace can meet your requirements in quality and delivery of NONLINEAR POTENTIOMETERS

Nonlinear precision wire-wound potentiometers in standard and subminiature sizes are now available in prototype or production quantities from Ace Electronics Associates . . . *and you can be sure of delivery.*



These new Ace nonlinear units incorporate the same advanced engineering, precision craftsmanship, and controlled quality which have made ACEPOT linear potentiometers standards of excellence.

A new Division directed by highly qualified engineers, special prototype section, and mass production facilities are at your service to meet your requirements for quality and delivery of nonlinear precision potentiometers.

For complete information . . .

Call or write William Lyon or Abraham Osborn, Nonlinear Division, outlining your requirements. Your inquiry will receive prompt attention . . . and you will get delivery as specified.

Featuring!

Highly developed design techniques achieve high resolution and close conformity for your unique nonlinear requirements.

* trademarks applied for

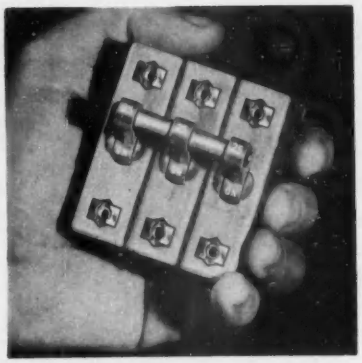
ACEPOT* ACETRIM*

ACE ELECTRONICS ASSOCIATES, INC.

Dept. C, 101 Dover St. • Somerville 44, Massachusetts

Telephone: MOnument 6-4802 • *Engineering Representatives in Principal Cities*

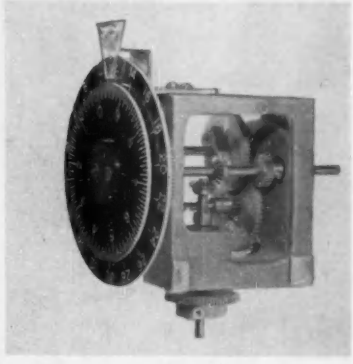
NEW PRODUCTS



FOR AC OR DC SERVICE

Shown is one of the Series AM-17 interchangeable circuit breakers for 400 cycle ac or dc. Designed primarily for airborne applications, the units can function without any change in rating or essential time-delay characteristics. They are manufactured in single pole form only, but can be readily linked with others for two- or three-pole companion-trip units. All models meet military aircraft requirements for shock, vibration, temperature, acceleration, and other factors.—Heinemann Electric Co., Trenton, N. J.

Circle No. **55** on reply card



NEW DIAL ASSEMBLY

Designed for miniature servomechanical breadboard systems, this low-inertia concentric dial assembly may be mounted so that the dial face is either parallel or perpendicular to the mounting surface. Unit is a two-speed indicator with standard ratios of 10:1 or 36:1. Other ratios are available on special order.—Reeves Instrument Corp., New York, N. Y.

Circle No. **56** on reply card

For More Information

from ADVERTISERS

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about NEW PRODUCTS

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ADVERTISER	PAGE NO.

CONTROL ENGINEERING
JULY, 1957

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CONTROL ENGINEERING
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(100) EXPLOSION ACTUATED VALVES. Conax Corp. Bulletin, 8 pp. This bulletin is based on talks delivered to the American Rocket Society. It describes the evolution of the company's explosive valves, covers normally open and normally closed models, and illustrates flow conditions before and after firing.

(101) SPECTROCHEMICAL ANALYSIS. Jarrell-Ash Co. Brochure CH402, 24 pp. Contains detailed descriptions of the design and application of a variety of excitation-source units and discharge stands used in spectrochemical analysis. It offers specifications of arc and spark units stands, end attachments, for direct reading and photographic analysis.

(102) BINARY NUMBER SYSTEM. IBM. "Data Processor" Vol. II, No. 1, 8 pp. This issue of the "Data Processor" leads off with a short explanation of binary arithmetic, the heart of electronic computer design. Also contains a tip on increasing magnetic-tape-storage capacity.

(103) ANALOG COMPUTERS. GPS Instrument Co., Inc. Booklet, 8 pp. Entitled "High-Speed Analog Computers, Key to Rapid System Development," this new booklet answers questions about automation and the development of control systems for industrial and military applications. Discusses the virtues and limitations of high-speed analog computers as compared with real-time computers.

(104) POWER RESISTORS. Ward Leonard Electric Co. Bulletin 12, 4 pp. Describes a complete line of power resistors designed to meet all requirements of the recent military specification, MIL-R-26C, on fixed wire-wound power type resistors. Dimensions, mounting covered.

(105) TIME-TEMPERATURE RECORDER. Avien, Inc. Publication No. 133, 8 pp. Analyzes the need for monitoring jet-engine temperature and explains operation of the company's TTR System. Shows how the system automatically logs engine temperatures and improves engine efficiency and flight safety.

(106) AIR-BRAKE-POWER OPERATORS. Rockwell Mfg. Co. Bulletin V-604, 4 pp. Catalogs a complete line of Westinghouse Air Brake power operators for actuating Rockwell-Nordstrom screw-gland, wrench-operated valves. Tables include size, cylinder diameter, length of stroke, for four operating conditions.

(107) SERVOMANOMETERS. Exactel Instrument Co. Bulletin 500, 8 pp. Describes design features and operation of the company's production model servomanometers. These units combine the precision of a liquid manometer with the utility of a servo instrument. Covers zero drift, accuracy, errors, and applications.

(108) CONTINUOUS WATER VAPOR RECORDER. Mine Safety Appliance Co. Bulletin No. 0714-1, 4 pp. Presents the company's latest equipment for measuring low concentrations of water vapor in air or other gaseous streams found in process industries and gas pipelines. Explains and illustrates the principle of operation, which is based on measurement of heat-energy exchanges.

(109) SERVOMOTOR-RATE GENERATOR. Beckman/Helipot Corp. Data Sheet 866, 2 pp. Covers the Model 18 MG 690/660, a 60-cycle, 115-volt, size-18 servomotor-rate generator. Sheet contains design information, specifications, characteristics, dimensional drawings, and torque-speed curves.

(110) VACUUM GAGES AND BAROMETERS. Precision Thermometer & Instrument Co. Bulletin D-2, 4 pp. Catalogs this company's line of mercurial

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barometers and vacuum gages, vacuum pump gages, and an absolute pressure gage. Descriptions include sizes, ranges, and applications.

(111) ULTRASONIC GAGING. Branson Instruments, Inc. Bulletin V-200, 8 pp. Describes an ultrasonic resonance instrument designed for use in fast, nondestructive tests. Separate sections cover applications, operating instructions, specifications, and accessories.

(112) INDUSTRIAL OIL-FILLED CAPACITORS. Industrial Condenser Corp. Catalog 1134, 4 pp. Contains information on a complete line of industrial high-reliability "G" type oil-impregnated capacitors for critical space and access.

(113) ELECTRONIC COUNTERS. Laboratory for Electronics, Inc. Bulletin 700, 4 pp. Describes a decade scaler that has a counting speed of 10 megacycles and a binary scaler with a counting speed of 20 megacycles. Also describes three preset scalers and three decade scalers with counting speeds of 20, 40, and 100.

(114) THERMOCOUPLE EXTENSION WIRE. Claud S. Gordon Co. Bulletin 1200-2, 2 pp. Illustrates a new polyvinyl jacketed thermocouple extension wire, detailing some of its advantages and outstanding features, and giving complete specifications on some of the common types.

(115) REVERSIBLE GEARED MOTORS. Barber-Colman Co. Catalog GR-2, 4 pp. Describes the company's type TYAZ-CE reversible geared motors, designed for servomechanisms, voltage regulators, combustion and industrial controls. Complete performance characteristics are tabulated on page 4.

(116) METHANE DETECTOR. Mine Safety Appliances Co. Bulletin No. 0809-4. Contains detailed information on the M-S-A Type W-8 Methane Detector, a portable instrument that will easily and accurately determine the methane content of mines.

(117) TELEMETERING SYSTEMS. The Vapor Recovery Systems Co. Bulletin CP-3012, 24 pp. Has some very interesting descriptions of the basic elements that combine to form pulse code telemetering systems. Lists sizes, ranges, power supplies, and special features.

(118) MAGNETICALLY REGULATED. Gulton Industries. Folder, 4 pp. Describes and illustrates a complete line of power supplies for filaments, strain gages, computers, and telemetering applications. Discusses the EM transistorized line (dc voltage regulators, etc.).

(119) INSTRUMENT SPECIFICATIONS. The Hays Corp. Condensed catalog, 12 pp. Actually a digest of specifications and performance characteristics on many of the instruments and controls manufactured by this company.

(120) SYNCHRONOUS CONVERTER. George Kent, Ltd. Publication 994/557, 2 pp. Illustrates and describes the company's new synchronous converter, available in 40, 50, and 60 cps models. Complete specifications and some typical applications also included.

(121) "FLUID POWER NEWS" The Oilgear Co. Newsletter, 4 pp. This new periodical will carry technical articles on fluid power components, controls and systems, and news of important developments in the fluid-power industry.

(122) NUCLEAR MAGNETIC RESONANCE ANALYZER. Schlumberger Well Surveying Corp. Tech-Talk No. 1, 6 pp. Gives a general description of the Model 104 NMR Analyzer, explains its operating principles, and lists complete specifications on the console and magnet units. Two pages are devoted to interpretation and applications of nuclear magnetic resonance. An actual chart record indicates the character of the output.

(123) THERMOCOUPLE ASSEMBLIES. Claud S. Gordon Co. Bulletin No. TA-457, 4 pp. Illustrates and describes a wide variety of standard Serv-Rite thermocouple assemblies, including straight and angle types. Also gives catalog numbers, sizes, prices etc.

(124) PNEUMATIC CONTROL EQUIPMENT. Leeds & Northrup Co. Folder ND4(9), 12 pp. Contains complete information about L&N's Speedomax G Pneumatic Control for steel, chemical, petroleum, and allied industries. Included are photos, schematics, and line drawings illustrating all pertinent details and operating principles.

(125) ACCELERATION EQUIPMENT. Genisco, Inc. Illustrated catalog presents four models of the company's G-Accelerators or centrifuges used to subject aircraft and guided missile components to simulated operational g-loadings. Special design and operational features, detailed specifications and engineering data for each model are given. Also covers a variety of speed-indicating, counting, and timing equipment.

(126) CONTACT METER-RELAYS. Assembly Products, Inc. Catalog No. 4-C, 40 pp. Supplies complete information on a line of meter relays designed for original equipment or self-contained control packages. Various circuits for different control actions are discussed. So are panel meters and auxiliary control components.

(127) MALFUNCTION DETECTOR. Robertshaw-Fulton Controls Co. Bulletin No. 600-5, 8 pp. Describes the Model 65 Vibraswitch Malfunction Detector and Control Units for protecting rotating equipment. Dimensional drawings and typical wiring diagrams are included.

(128) FLOWMETER SELECTION. Neptune Meter Co. Bulletin 566, 28 pp. This completely revised bulletin helps the

process engineer select the best meter-register combination for standard industrial liquid-metering jobs. Chart covers construction details, liquids that can be handled, register types, and meter sizes. Accessories, installation directions, and numerous application photos also included.

(129) MAGNETIC CLUTCHES. Fawick Corp. Bulletin M-101, 6 pp. Provides dimensional drawings and specifications on three types of magnetic clutches: stationary field, spring-engaged electrically-released, and spring-engaged electrically-released with rectifier.

(130) IR RESEARCH AID. Servo Corp. of America. Bulletin 1256, 8 pp. This reprint from "Aviation Age" describes the operation and application of the company's Airborne Infrared Monochromator for observing radiations from other aircraft and missiles. Diagrams show the optical system and some of the electronic circuitry.

(131) STEAM AND LIQUID CONTROL VALVES. O. C. Keckley Co. Condensed Catalog No. 57. Illustrates and describes over 50 products. Among them: temperature and pressure regulators; solenoid, diaphragm, motorized, and float valves; pressure reducing, flow control, safety and relief valves; and strainers.

(132) MULTI-CHANNEL SCOPES. Electronic Tube Corp. Catalog, 28 pp. Covers the company's complete line of standard two- and four-channel oscilloscopes, strainalyzers, and related dc amplifiers. New items include a two-channel scope with a vertical frequency range from dc to 15 megacycles, and an extremely versatile four-channel recording oscilloscope and master strainalyzer.

(133) HIGH-SPEED ROTARY SWITCHES. Instrument Development Laboratories, Inc. Bulletin, 4 pp. Physical features and performance data on a new line of high-speed rotary switches for long-life airborne applications in telemetering, sampling, and programming.

(134) TEMPERATURE MEASUREMENT. Bailey Meters & Controls, Ltd. Product Spec E51-8, 4 pp. Contains a complete technical description of the company's strip-chart temperature recorder and components. Among the latter covered: galvanometer, chopper bar, chart drive, printing ribbon drive, and automatic station selector. Last two pages list specifications and physical characteristics of the recorder and measuring elements.

(135) VERSATILE DIGITAL RECORDER. Hewlett-Packard Co. Journal, Vol. 8, No. 7, 4 pp. Describes the special features of a fast digital recorder that has an analog output for automatic data plotting. Photographs and drawings help explain the actual operation of the unit.

(136) NEW ANALYTICAL INSTRUMENT. American Instrument Co., Inc. Bulletin 2278, 4 pp. Presents the Aminco-Bowman Spectrophotofluorometer, a brand new analytical instrument that combines the advantages of spectrophotometry with the sensitivity of fluorescence measurement. Schematic drawing showing the principle components is accompanied by a discussion of the instrument's operation. Specifications and typical uses are covered.

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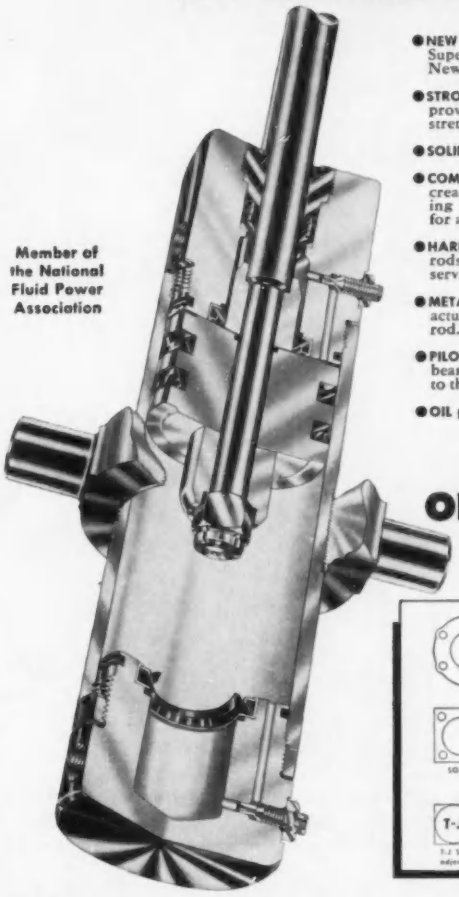

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- STRONGER than outmoded tie rod design, proven through actual tests. No tie rods to stretch.
- SOLID STEEL HEADS throughout the full line.
- COMPACT DESIGN eliminates tie rods, increasing the strength and reducing mounting space required, providing extra room for adjacent equipment.
- HARD CHROME PLATED body bores and piston rods . . . assure you of long trouble-free service. (Standard at no extra cost.)
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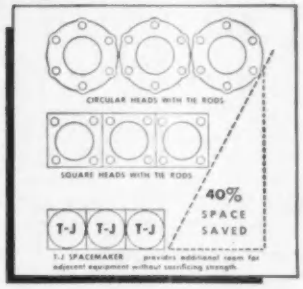

You *save 40% space* when you switch from outmoded tie rod cylinders to the T-J Spacemaker! It's stronger, too! Fits right into automation programs in countless plants. Delivers top performance and dependability with a big *plus* in advanced features. Wide range of styles, capacities . . . reduces man-hours and costs in all kinds of push-pull-lift jobs. Off-shelf delivery in 64,000 combinations!

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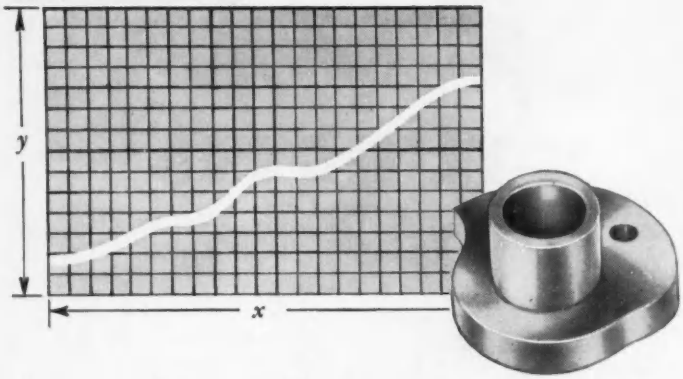
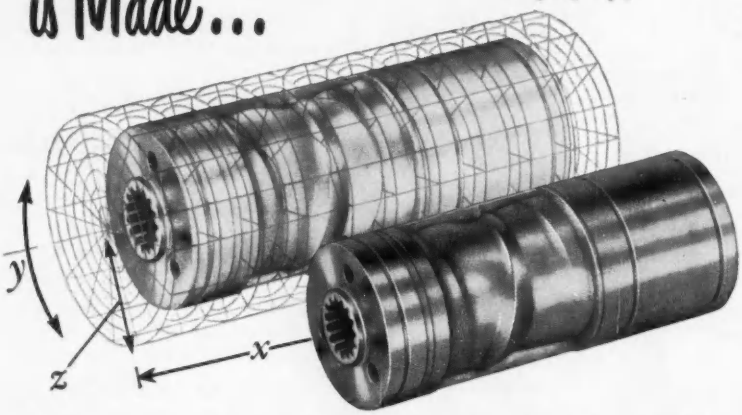
Here's How a 2 Dimensional Cam is Made...



Here's How a 3 Dimensional Cam is Made...

$z = f(x,y)$



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Send today for the new, fact-filled Parker folder—discover how Parker can engineer and build three dimensional cams with an infinite number of precisely machined stations to serve as the "brains" for a wide range of automatic operations.

THE PARKER-HARTFORD CORPORATION
CAM DIVISION
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by Parker

WHAT'S NEW

(Continued from page 36)

of its grinders rather than magnetic amplifiers. There is some sacrifice in reliability, but a lot of savings in cost. He sang the praises of Cypac, pointing out that circuit modification of a static system is a matter of minutes, whereas rewiring an electromechanical panel can take between four and five hours. He added that one of Springfield's Cypac-equipped grinders has run for two years with absolutely no control problems.

The other surprise also involved static switching systems. "It is extremely interesting," said By, "that during this whole meeting nobody mentioned input devices to these systems. Last year they were ballyhooing proximity switches and contactless pushbuttons. What happened?"

• **Some interesting papers**—This issue of CONTROL ENGINEERING carries several abstracts (page 192) of Westinghouse papers given at the forum. They deal with: teleological control systems (Albert Kerstukos, development engineer in the New Products Engineering Dept.), the new Dynistor diode (A. P. Kruper, supervisor of application engineering in the Semiconductor Dept.); and the progress of Cypac (W. B. Weathers, manager of the General-Purpose Control Sales Dept. in the Motor & Control Div., and R. A. Clark, supervisory engineer in the Standard Apparatus Group of the Director Systems Dept.).

Kerstukos likened Westinghouse's teleological, or self-adaptive, systems to the human being in that they control by intelligent experimenting rather than by fixed logic. These systems are particularly useful in cases where complete process characteristics are not known (in certain flow-process applications, for example), because they can be designed to maintain near optimum regardless of the change in measured variables. The system was demonstrated by means of a contour map with higher potential on each increasing constant elevation line. The object was to derive a contact that could move in x-y coordinates toward the point of highest elevation. It provoked quite a bit of interest and many good questions.

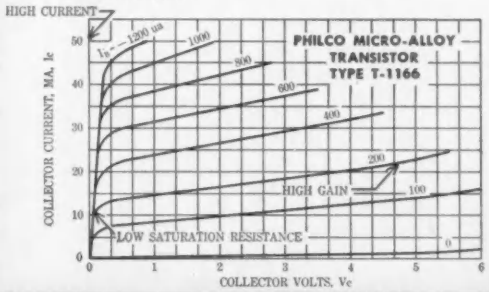
• **A unique diode**—The Dynistor diode, said Kruper, has conventional forward characteristics but unusual reverse ones, permitting it to be used as a switch. He was unable to say much more about it because of some patent difficulties, but he did manage

F-l-a-s-h!...from Transistor Center, U.S.A.

Announcing a new transistor class... The PHILCO Micro-Alloy Transistor (MAT)*

CHECK THESE UNEQUALLED FEATURES

- **Excellent High Speed Switching characteristics.**
- **Low Saturation Voltage (low impedance)**
- **Excellent high frequency amplification.**
- **Excellent low-level amplifier over entire frequency range from D.C. to Megacycles.**
- **Exceptionally Long Life (hermetically sealed)**
- **Permits high speed computer design with Fewer Stages.**



...world's first production transistor with exceptionally high frequency and high gain... plus low saturation resistance!

This newest development from Philco Transistor Center features the characteristic high frequency response obtainable with extremely precise base width control. Designed for low voltage operation, the new MAT transistor is especially well suited for high speed applications where low saturation resistance (reduced power consumption) is necessary.

To combine high gain at high currents with high frequency response, the new MAT transistor employs a gallium doped alloy junction for the emitter electrode.

A special short-alloying cycle, combined with precise electro-chemical production techniques (pioneered and developed at Philco Transistor Center for production of SBT), results in the micro-alloy contact for exceptionally high injection efficiency. This new process assures higher gain, and permits operation at higher current. Beta linearity is excellent over the entire range of operating currents... up to 50 milliamperes.

• **Write for complete information** *and specifications. Make Philco your prime source of information for high frequency transistor applications.*

**Patent Applied For*

"Visit the Unique Philco Transistor Display at WESCON Show, San Francisco Cow Palace, August 20-23, Booth #2217-2218".

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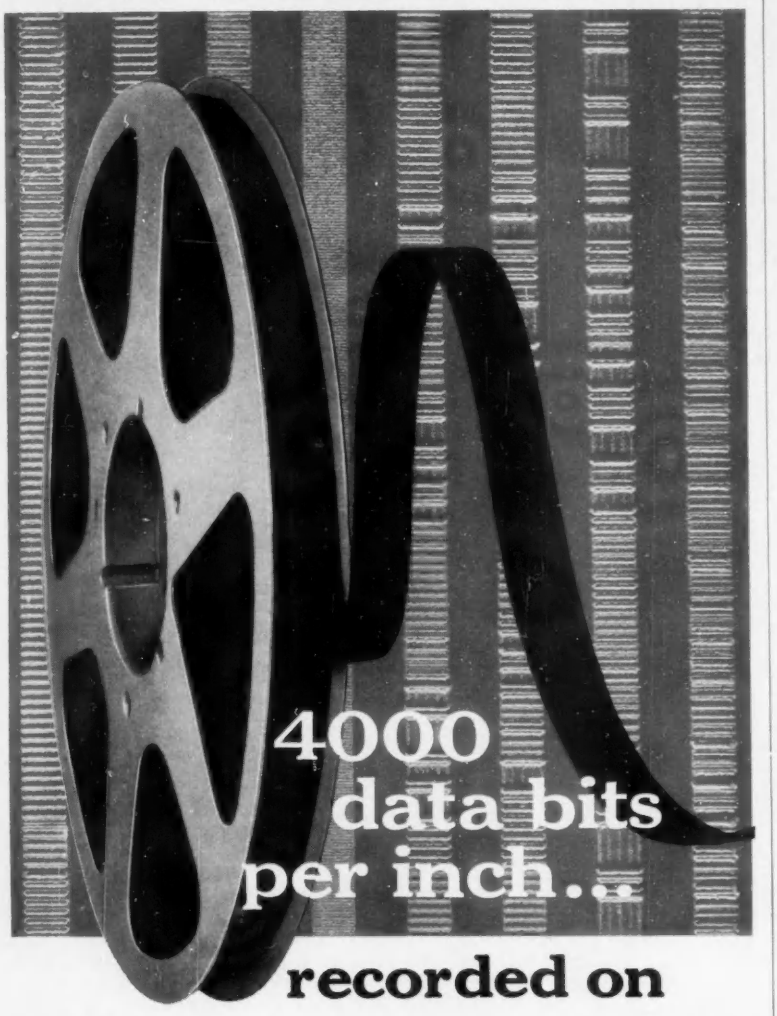
Microphotograph of pulse recording on Soundcraft Instrumentation Tape



recorded on

SOUNDCRAFT type "A" INSTRUMENTATION TAPE

and played back without error!

In the new Rocketdyne IDIOT* II computer system, 4000 data bits (over 500 bits of information per channel, per linear inch) have been stored in an inch of Soundcraft Type "A" Instrumentation Tape... double the amount of information that has been stored in equivalent lengths of competitive tapes! What made the difference? Soundcraft Type "A" Tape ... the only tape engineered specifically for pulse recording. Its special RCCH oxide formulation provides an extremely hard surface with high thermal softening point – prevents imbedding of foreign particles. The formulation is uniformly applied to the durable Mylar† base by patented Uni-level process; then Micropolished to remove surface irregularities. These exclusive design features assure you of error-free pulse recording with Soundcraft Type "A" Instrumentation Tape. Write for Soundcraft Type "A" Instrumentation Tape Brochure.

*Rocketdyne Instrumentation Digital On-Line Transcriber. †Dupont T. M.

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WHAT'S NEW

to throw out this tantalizer: there is a possibility that the diode may represent the solution to the output amplifier problem in static switching systems.

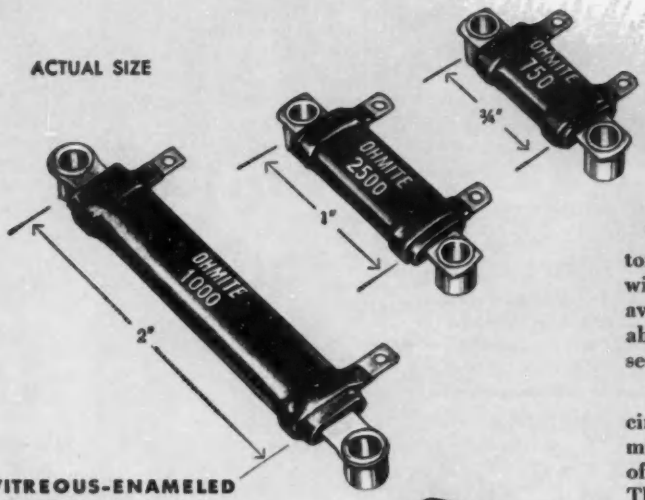
More than 6,000 Cypac modules, Weathers reported, have been built into a complete plant conveyor programming system for the new Plymouth assembly plant in Newark, Del. Then Clark got up to say that *none* of the new Cypac modules have had any basic failures to-date. New Cypac components, Clark added, are being developed as the needs become known. Furnished recently: new load-control output amplifiers that can supply the required in-rush current to inductive devices such as solenoid-valve coils; a new shift register element for conveyor control or automatic testing systems.

• **Other sessions**–R. B. Colten of General Motors' Process Development Section said that some of the industrial electronic equipment GM has purchased is very poorly constructed and there is a crying need for standards in this area. "He showed," By said, "typical wiring diagrams supplied by electrical suppliers, which were just free-hand sketches that did not list any parts and were practically impossible to understand." GM is making up its own electronic standards, taking the best from those of MIL, AIEE, RETMA, and JIC, and revising them for its own use.

G. H. Royer, senior engineer in Westinghouse's Director Systems Dept., discussed the transistorized NOR logic block, pointing out that all the primitive logic functions can be performed with this basic element. Packaging and wiring to take advantage of its small size is still a problem, but this just spices up the rumor that the NOR circuit is used in all the new Westinghouse steel-mill program control equipment. Royer said that it looks like the cost will be comparable to that of Cypac elements.

Jerome A. Raterman, president of The Monarch Machine Tool Co. and president of National Machine Tool Builders' Association, took off on the colorful theme, "Galloping Obsolescence" or the problems faced by the man who sells machine tools. There are two meanings to obsolescence, he said. One is "worn out" and the other is "gone out of use". It used to be that machine tools were used until they were worn out, but with today's rapid advances in control sys-

...pack higher wattage into less space with NEW MINIATURE OHMITE® THIN-TYPE power resistors



VITREOUS-ENAMELED COVERING holds winding rigidly in place . . . protects winding from damage.

UNIFORM WINDING prevents "hot spots" and resultant failures.

STRONG, CERAMIC CORE provides a solid base for winding. Core unaffected by cold, heat, or high humidity.

INTEGRAL MOUNTING BRACKETS distribute heat more evenly throughout resistor and conduct heat away.

The new Ohmite *miniature* thin-type power resistors are now available in three wattage sizes in a wide range of resistance values; two wattage sizes are available from stock; also three wattage sizes available from stock in the standard thin-type resistor . . . see (*) table below.

Designed especially for use in modern electronic circuitry where space is at a premium, these new miniature units have all the timeproven superiority of standard Ohmite vitreous-enameled resistors. They are only ⅛" thick and ⅜" wide, and range in length from ¾" to 2".

Because of their compact design, the new Ohmite *miniature* thin-type resistors pack higher wattage into less space. The stacking bracket allows mounting close to the surface and a hollow stud provides for convenient stacking of two or more units. The miniature thin-type rises only 11/32" above the mounting surface; stack mounted, four units are less than 1⅛" in height. Shown in photograph are: 1 Standard Thin-Type Resistors with Unit Brackets; 2 Standard Thin-Type Resistor with Stacking Brackets; 3 Miniature Thin-Type Resistors.

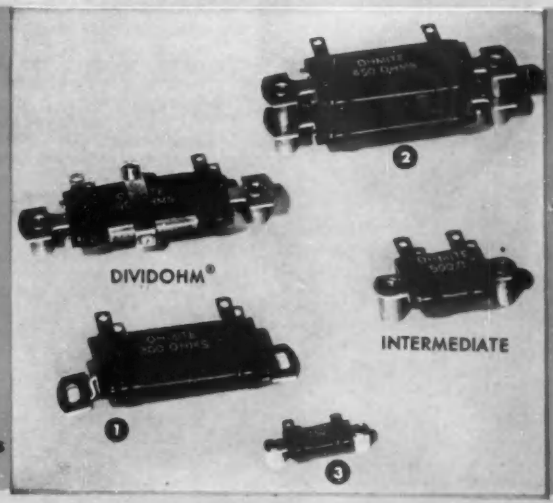
Write on company letterhead for Bulletin 138-B.

MINIATURE THIN-TYPE RESISTORS Watt Rating	Length of Core	Width of Core
* 10	¾"	⅜"
15	1"	⅜"
* 20	2"	⅜"
INTERMEDIATE THIN-TYPE RESISTORS		
20	1"	13/16"
30	1½"	13/16"
STANDARD THIN-TYPE RESISTORS		
* 30	1¼"	1"
* 40	2"	1"
* 55	3½"	1"
65	4¾"	1"
75	6"	1"

Now available from stock . . .

2 miniature sizes: 10 and 20 watts

3 standard sizes: 30, 40, and 55 watts



WATTAGE RATINGS ARE BASED ON THE RESISTOR MOUNTED ON A HORIZONTAL STEEL PANEL .040" THICK BY 10" SQUARE. RATINGS SHOULD BE REDUCED APPROXIMATELY 15% FOR NONMETALLIC MOUNTING SURFACE.

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RHEOSTATS • RESISTORS • RELAYS • TAP SWITCHES • TANTALUM CAPACITORS

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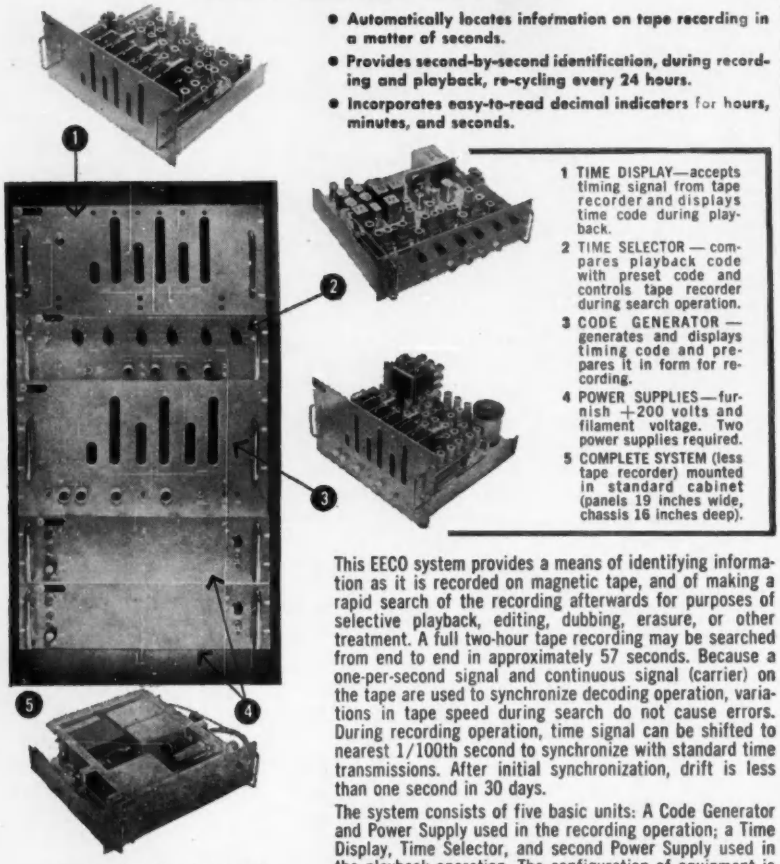
Another EECO FIRST!

TIMING, SEARCH, AND CONTROL SYSTEM FOR TAPE RECORDERS



- Automatically locates information on tape recording in a matter of seconds.
- Provides second-by-second identification, during recording and playback, re-cycling every 24 hours.
- Incorporates easy-to-read decimal indicators for hours, minutes, and seconds.

1 TIME DISPLAY—accepts timing signal from tape recorder and displays time code during playback.
2 TIME SELECTOR — compares playback code with preset code and controls tape recorder during search operation.
3 CODE GENERATOR — generates and displays timing code and prepares it in form for recording.
4 POWER SUPPLIES—furnish +200 volts and filament voltage. Two power supplies required.
5 COMPLETE SYSTEM (less tape recorder) mounted in standard cabinet (panels 19 inches wide, chassis 16 inches deep).

This EECO system provides a means of identifying information as it is recorded on magnetic tape, and of making a rapid search of the recording afterwards for purposes of selective playback, editing, dubbing, erasure, or other treatment. A full two-hour tape recording may be searched from end to end in approximately 57 seconds. Because a one-per-second signal and continuous signal (carrier) on the tape are used to synchronize decoding operation, variations in tape speed during search do not cause errors. During recording operation, time signal can be shifted to nearest 1/100th second to synchronize with standard time transmissions. After initial synchronization, drift is less than one second in 30 days.

The system consists of five basic units: A Code Generator and Power Supply used in the recording operation; a Time Display, Time Selector, and second Power Supply used in the playback operation. The configuration of equipment is entirely flexible, depending upon the desired application. The entire system may be assembled at one location, as illustrated, or the recording and playback functions may be separated for use with different tape machines.

Operates with any tape recorder meeting these primary requirements:

1. Two or more tracks, one for the time code.
2. Provision for remote control.
3. Capability of playback at fast forward and rewind speed.
4. Bandpass adequate to reproduce the time code faithfully at any tape speed encountered during search operation.

For complete description and specifications, ask for Bulletin S-2856-E.

ELECTRONIC ENGINEERS AND PHYSICISTS

Interesting and challenging work in systems and related projects offers unusual employment opportunity at EECO. Send a resume of your qualifications to the attention of R. F. Lander.

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tems and in the tools themselves, they become uneconomical to operate long before they wear out. If you want to stay in business, he said, use the best capital equipment; if you want to sell successfully, know the cost and profit situation.

• **Basic or applied?**—"New Horizons" noted by NMTBA's Executive Vice-President Ludlow King included the fast approach of recorded information control—"not as fast as predicted by some, but much faster than predicted by the conservatives"; a practical, as compared to a basic, trend in machine tool builder research ("Although," By said, "I noted in a survey of the whole industry last year that five or six companies are setting up separate divisions for basic research"); and an increase in the number of electrical controls per machine tool (the primary reason for an average price jump from $5,000 in 1947 to $13,000 in 1956).

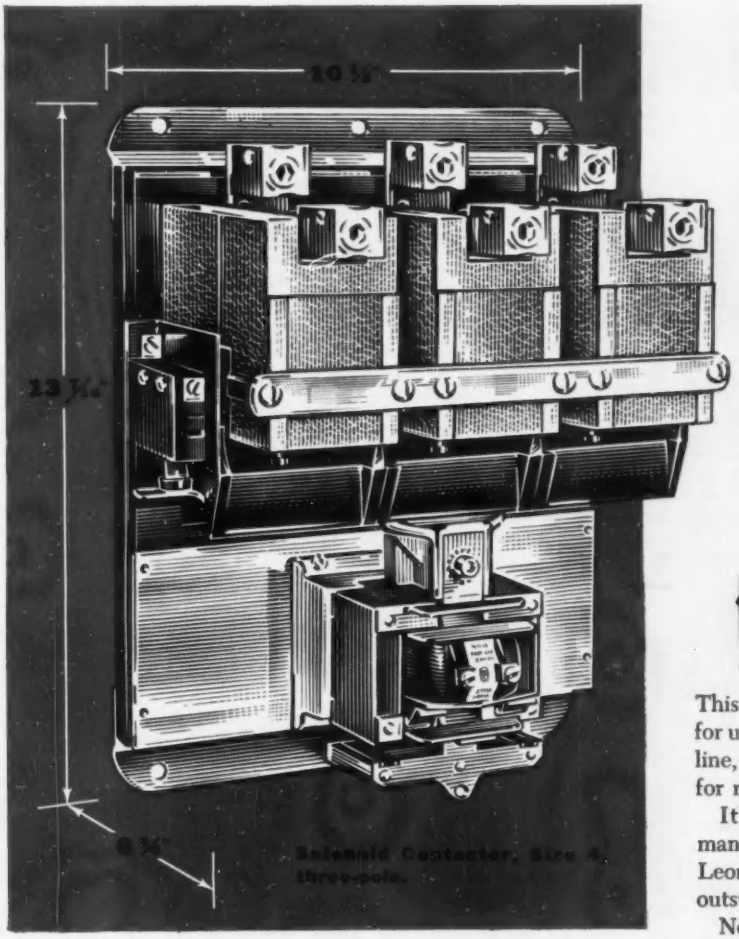
K. E. Birrell of The Sheffield Corp. introduced the Monitorecord, a 14-channel on-off recorder that times the sequence of events on automatic machines. By itself, it is useful for setting up machines; with plug-in features it can perform intermittent checks on machine operation. Standard units accept 115-volt, 60-cycle signals. It's a pretty simple device and could be quite useful.

SAMA Members Prosper, But Worry About Technology

Meeting at the Greenbrier, White Sulphur Springs, W. Va., April 28-May 2, the Scientific Apparatus Makers Association reported that sales in '56 were above those in record-breaking '55. The Industrial Instrument Section, with a 21-percent increase, led all other sections, including the Recorder-Controller Section. Retiring President H. F. Dever pointed out factors which should keep instrument sales curves rising:

- ▶ technology is rapidly making equipment and processes obsolete
- ▶ more and more billions are scheduled for industry's research and development
- ▶ military programs concerned with missiles, rockets, and radar will increase demand for test instrumentation.

Members were warned by Ross Nichols, vice-president of Weston Electrical Instrument Corp., that they run the risk of losing control of technical know-how "developed over a long period of years at costs many



Solenoid Contactor, Size 4, three-pole.

NEW 150-amp solenoid contactor extends proven line

This new Size 4 A.C. solenoid contactor is ideal for use in motor starters and controllers for main line, accelerating and reversing purposes and for resistance heating and lamp loads as well.

It's the new Bulletin 4454—incorporating many advanced design features found on Ward Leonard's Sizes 0 to 3 contactors. Check these outstanding features:

New sintered-silver-cadmium-oxide contacts—can repeatedly handle high inrush currents without a sign of contact welding, excessive pitting or other damage.

Simple, compact solenoid design—excellent for modern metal control panels using accessible front-of-board wiring, particularly useful where panel space is limited.

Available with two or three main poles and up to 4 side-mounted auxiliaries. Also with provision for mechanical interlocking and addition of overload relays.

Completely described in Bulletin 4454. Write for your copy today. The Ward Leonard Electric Co., 9 South Street, Mount Vernon, New York. (In Canada: Ward Leonard of Canada Ltd., Toronto.) 7.6

ENGINEERING DATA

Size 4 A.C. Contactor Ratings*

Service	8-Hour Ampere Rating		Enclosed Power Rating	
	Open	Enclosed	Three Phase Volts	H.P.
Across-the-Line Starting	150	135	110 220 440-550	25 50 100
Across-the-Line Plug-Stop or Jogging	150	135	110 220 440-550	15 30 60

Service	8-Hour Ampere Rating	Single Phase Volts	Single Phase K.W.	Three Phase Volts	Three Phase K.W.
Resistive Heating Load**	150	110 220 440 550	15 30 60 75	110 220 440 550	26 52 105 130
Tungsten Lamp Lighting or Infrared Heating Load**	120 Amperes for 250 Volt Circuits or Less				

*The ratings listed are those recommended by the National Electrical Manufacturers Association.
**These ratings apply to open or enclosed contactors.

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WARD LEONARD ELECTRIC COMPANY
MOUNT VERNON, NEW YORK

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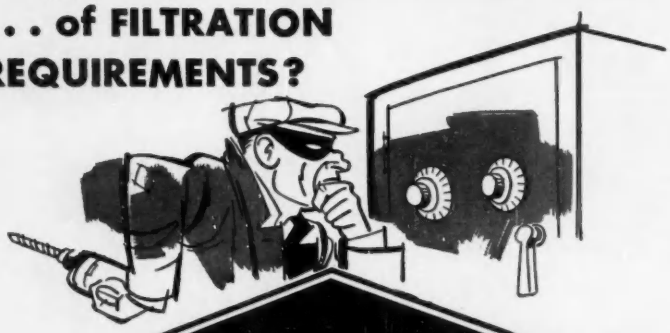
...of FILTRATION REQUIREMENTS?



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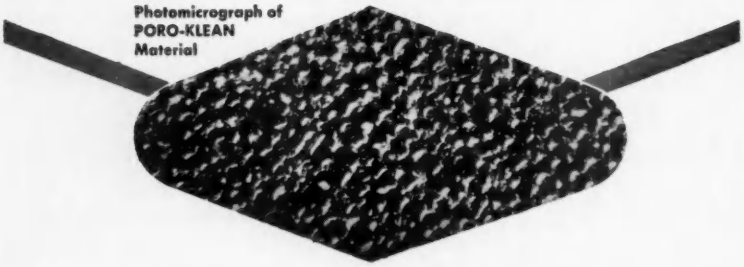
THE POROUS STAINLESS STEEL MEDIUM THAT OFFERS YOU ALL THESE ADVANTAGES—

- **HIGH HEAT RESISTANCE** . . . permitting operation at temperatures as high as 900°F.
- **HIGH TENSILE STRENGTH** . . . up to 15,000 psi, allows Poro-Klean Filters to withstand differential pressures of more than 3500 psi and to handle extremely viscous liquids at relatively high flow rates.
- **HIGH CORROSION RESISTANCE** . . . allows the filtration of — or cleaning by — substances that would quickly damage other filter materials.
- **NO MEDIA DISCHARGE** . . . Cuno's unique manufacturing and control methods result in a much stronger material with *all* particles securely bonded at several points of contact. Independent tests have *proved* that Poro-Klean produces no product contamination due to media discharge . . . even under conditions of extremely high differential pressures and severe vibration.
- **UNIFORM FINE FILTRATION** . . . with standard material down to 5 microns. Material for sub-micronic filtration available on special order.



Photomicrograph of PORO-KLEAN Material

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times what may be recovered on a government contract . . . of a few thousand dollars . . . because the government may require them to give it license to have the contract product made by others".

SAMA, also worried over the scarcity of technical manpower, proposed a nationwide task force of neighborhood science advisory groups voluntarily staffed by professional engineers and scientists. The proposal has received favorable consideration from the Scientific Manpower and the Engineering Manpower commissions, according to Dever.

Two weeks after the parent association met, the Recorder-Controller Section held a conference of members' engineering executives at Skytop. There its Electric Transmission & Control Signal Standardization Committee reported on electric codes classification for nuclear reactor hazards. It studied two possible new projects significant to control engineers:

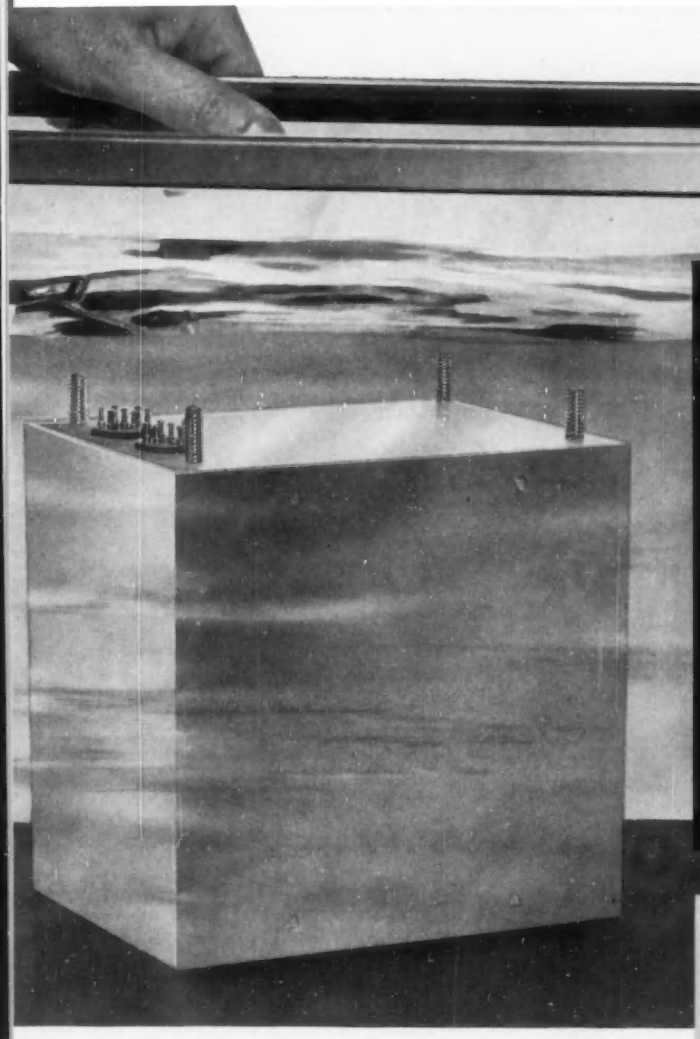
- standardization of both electronic and pneumatic controller markings
- dynamic analysis procedures.

Fluid Controls Institute Readies Valve Standards

May 8-11 the Fluid Controls Institute, made up of manufacturers of automatic regulating valves, control valves, solenoid valves, and steam accessories, followed SAMA to The Greenbrier, and elected new officers: John S. Leslie, Leslie Co., president; Dean E. Madden, A. W. Cash Valve Mfg. Corp., first vice-president; Marshall B. Taft, Minneapolis-Honeywell Valve Div., second vice-president; Paul K. Rogers Jr., Skinner Electric Valve Div., Skinner Chuck Co., treasurer; and Ed Glimske, Cochrane Corp., secretary.

Two sections indicated that they were well along on standard practices, the Control Valve Section with standards for testing valve capacity and leakage, and the Solenoid Valve Section with near-final agreement on the C_v (control valve terminology) method for stating flow capacity.

Instrumentation and controls for the first atomic-powered merchant ship will be designed by George G. Sharp, Inc., New York marine design firm, and Walter Kidde Nuclear Laboratories, Inc. The atomic power plant will use a pressurized water reactor.



Lambda makes own transformers, seals them hermetically, uses military-standard moisture-control test

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for COM-PAK® power supply transformers

Every Lambda Com-Pak power supply transformer gets a pre-installation soaking in hot water. A single bubble and the transformer is rejected. The unit installed in your Lambda Com-Pak power supply has passed this military test...assurance of long, trouble-free service.

This extra protection against moisture is one of a right-down-the-line set of Com-Pak quality control standards enforced by the world's largest exclusive manufacurer of power supplies. In-service satisfaction is the reason engineers who specify power supplies consistently name Lambda "first choice"...to the tune of 2½ times over the next identified manufacturer.

NEW COM-PAK SERIES SAVES PANEL SPACE

New 1.5 amperes model (illustrated) is available in three voltage ranges, needs only 8¾" of panel height, from $550. Other space-saving models from 200 MA (5¼"), priced from $169.50.

Lambda manufactures a complete line of regulated DC power supplies with current ranges through 1.5 amperes. Use the coupon to get the new 1957 catalog.

LAMBDA
Electronics Corp.

The first name in power supplies

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LAMBDA Electronics Corp., Dept. CE-757
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- Electrical Computers and Telemetering Systems
- Electro-Mechanical Bandpass Filters

Frahm Oscillator Controls, Type ROC, make possible the design and construction of inexpensive, precision tone generators that are small and light weight. These generators will have accurate output frequency and output voltage with very nearly sinusoidal wave shape.

They can be made with any one nominal control frequency between 20 and 1100 cps. They will control the output frequency of circuits, under specified conditions, constant within ±0.15% of the nominal control frequency.

We particularly encourage your inquiries and correspondence on special applications and problems. If you haven't explored these Frahm Oscillator Controls we'll be glad to send you complete specifications, characteristics, etc. Write for Bulletin 34-CE.

B-706

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WHAT'S NEW

UAW Win Reversed

Control engineers and technicians at Minneapolis-Honeywell vote "no union" to upset auto workers' March election victory.

United Auto Workers' representation victory at Minneapolis-Honeywell (CtE, May, p. 32) turned out to be short-lived. Union leaders had barely finished celebrating the easy triumph over Engineers & Scientists of America—marking UAW's first foray into engineer unions—when M-H engineers and technicians voted lopsidedly to decertify in a NLRB election held in mid-May. The score:

	Engineers	Technicians
Eligible to vote	1,451	746
Against any union	896	404
For UAW	314	254
For ESA	197	62

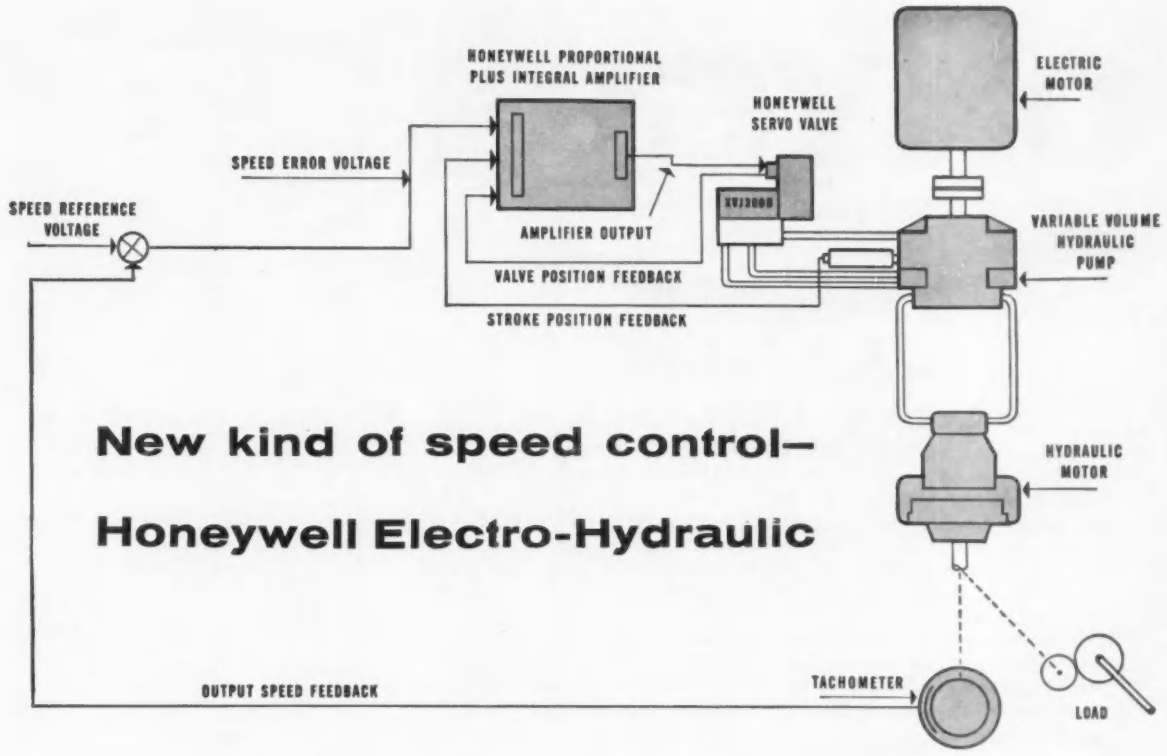
The vote not only snubbed UAW but also rejected federation leadership, which has represented both engineering and technical personnel at Honeywell for more than a decade. In addition, it appeared to be convincing substantiation of the company's position that professional engineers did not want a union to represent them.

• **What happened?**—Events at M-H were set in motion last January when a faction of Honeywell engineers became dissatisfied with ESA and asked UAW to represent them. The Detroit union, anxious to establish a beachhead among professional employees in the electronics and aviation industries, answered the call eagerly. In short order, the auto workers petitioned NLRB for a representation election and won an overwhelming victory over ESA.

Almost at the same time, another group of M-H engineers became dissatisfied with union representation altogether and petitioned NLRB for a decertification election. Citing this petition and the change in affiliation, the control company then challenged the federation's right to continue as a bargaining representative. The mid-May election resulted.

• **Union stunned**—UAW officials were stunned by the sudden turnabout. They had expected a close election, but were confident of victory. The union had over 900 dues-paying members on the rolls in April; they looked for 600 engineers to vote UAW and most of the technicians.

First union reaction to the decertifi-



New kind of speed control—

Honeywell Electro-Hydraulic

Only an electro-hydraulic speed control system can give you all these advantages.

- Wide speed range—ranges of 1,000 to one are readily possible
- Smooth, steady, low-speed operation
- Fast response
- Negligible droop under load
- Infinitely variable speed control
- Easily adjustable speed

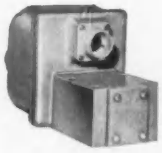
THE SPEED CONTROL diagram above is a typical example that shows the flexibility of Honeywell Electro-Hydraulic Control systems.

Honeywell servo valves and transistor amplifier combinations make new building blocks available for dozens of applications.

Rugged and dependable, they are smaller and more compact, have high speed of response, are easy to adjust and inexpensive to install.

For complete information, including realistic delivery dates, call, wire or write Minneapolis-Honeywell Machine Controls Division, Dept. CE-7-210, Minneapolis 8, Minn.

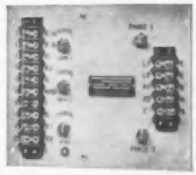
Flexible building blocks to do the job



3-Way Valve (XVJ300)
Output Flow (no load)
100 psi—3.5 gpm
1000 psi—9.9 gpm

4-Way Valve (XVJ303)
Output Flow (no load)
100 psi—1.5 gpm
1000 psi—5.0 gpm

3-Way Valve (XVJ302)
Output Flow (no load)
100 psi—2.0 gpm
1000 psi—6.0 gpm



Amplifier (XRJ301)
Transistor Servo Amplifier
High gain, multiple input amplifier with superior reliability.

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OXYGEN ANALYZERS!

Oxygen is one of the most important factors found in modern chemical and industrial processes. Whether to minimize product oxidation (prepared atmospheres, air infiltration, etc.) ... or to insure adequate oxygen for efficient combustion (boilers, kilns, etc.) ... or to control oxygen for proper process operations (ammonia, acetylene, air fractionation, etc.) oxygen control has become too important in today's operations for any profit-minded executive to overlook.

And because they are the *only* instruments that measure oxygen content directly, accurately and conveniently, Arnold O. Beckman Oxygen Analyzers have become the leading instruments for modern oxygen control in a wide range of applications—from catalytic refineries to cement kilns—from power plants to personnel protection.

These instruments (and systems) can be built to meet *your individual* needs.

These instruments offer many unique advantages...

SELECTIVITY: Highly sensitive to oxygen. Effects of gases other than oxygen are negligible.

HIGH ACCURACY: 1% of full scale (Example: ±0.05% O_2 on range 0-5% O_2).

MANY RANGES: Full scale ranges from 0-1000 ppm or up to 0-100% O_2 available. Combustion ranges 0-5, 0-10, 0-15% O_2 supplied with 0-25% O_2 check range. Multi-range instruments available.

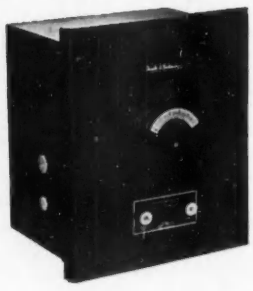
RAPID RESPONSE: Standard Analyzers—95% response in less than 1 minute. Special Units—95% response in 7 seconds!

USE ANY RECORDER: Millivolt output for potentiometers; current output for miniature electronic recorders and galvonometers; air output for pneumatic receivers and control systems.

PACKAGE UNITS: Analyzers and controls may be built into a cubicle with sampling components wired, piped, and ready for installation as a single unit.

SAMPLING SYSTEMS: Complete standard systems—components, package or portable units are available.

OTHER ADVANTAGES: Instruments may be mounted in explosion-proof cases, mounted indoors or outdoors, in portable panels, and have other desired features.



Model F3: Ranges of 0-1%, 0-5%, 0-10%, and higher. Meter on door for convenient readings at sampling point.

Model G2: Full scale ranges 0-0.1%, 0-0.5%, and others for low O_2 content. Ranges 90-100%, 95-100% O_2 for high O_2 content.

The above are but two of the complete line of Arnold O. Beckman Oxygen Analyzers available for every requirement.

Send for helpful free literature which describes Arnold O. Beckman instruments in detail. When writing, outline your particular application—we'll gladly supply specific information.

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ANALYZERS

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cation vote was surprise; second was to call "foul". Some leaders talked about filing unfair labor practices against the company. But after looking at the election figures top UAW leaders admitted that "they had been outmaneuvered".

Glenn E. Seidel, M-H vice-president in charge of engineering, said, "The election establishes the majority wish of our engineering and technical people." As a result of the vote, neither the engineers or technicians at M-H will be represented by a union. NLRB rules bar a second election for 12 months.

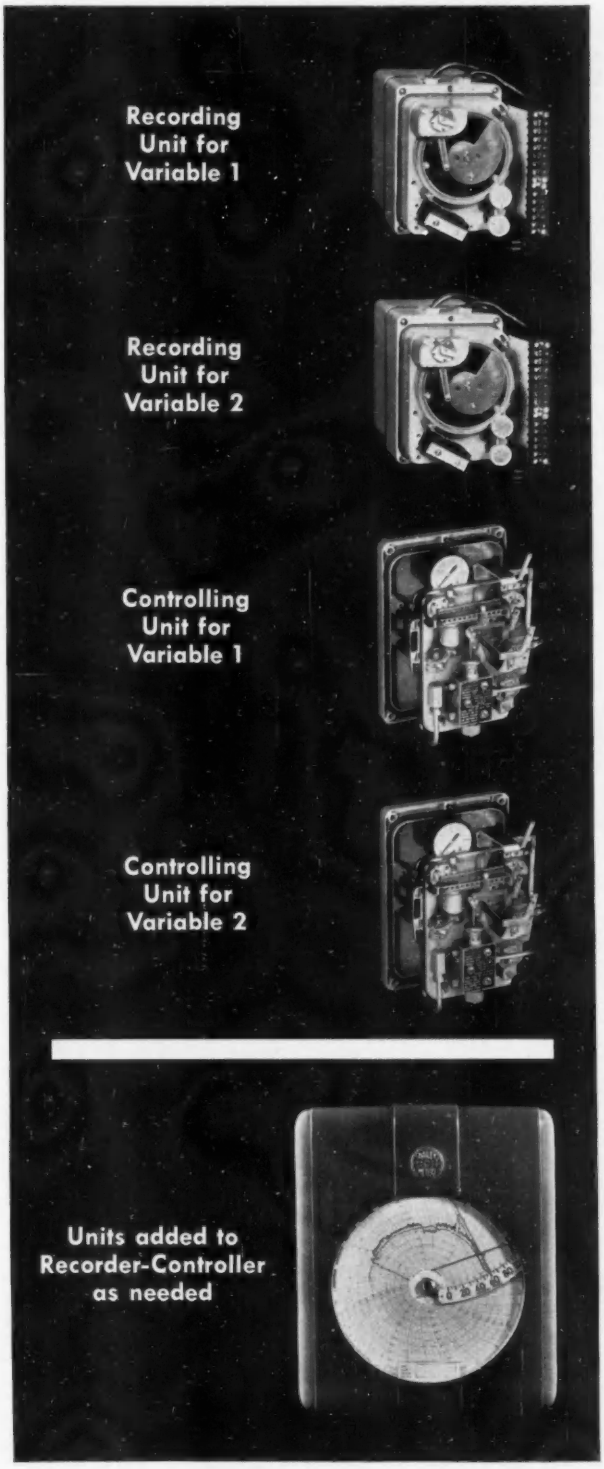
• **Dig in for trouble**—But while a calm moves in in Minneapolis, aircraft companies in California report intensified union activity among engineers and technicians. At several of the aircraft companies, engineers are represented by independent unions or affiliates of ESA. Strong action is being taken by these locals to bolster the organization against possible UAW raids. And UAW is looking for a soft spot to make an organizing beachhead which will replace the one lost at Minneapolis-Honeywell.

From Detroit comes word that UAW is determined to try again in the professional field. And this time, the union will launch a full-fledged program, incorporating what it learned in its Minneapolis setback.

Foundation for I,E&R Follows Through on First Projct

The new Foundation for Instrumentation, Education & Research shook the sawdust off its brand new limbs last month and followed through on the first of several top-notch projects. Like most of its other projects, which are still in the works, this one was suggested by an FIER board member, in this case John H. Heller, director of the New England Institute for Medical Research. The success of the "Conceptual Clinic for New Instrumentation for Medicine and Biology" (June 10-11) furnished concrete proof of a point that many forward-looking people have been pushing for a long time: that improvements in medical instrumentation will some about only if doctors and engineers can share their specialized knowledge on a common platform.

Just before the two-day clinic opened at Ridgefield, Conn., the foundation put a few final brushstrokes to its corporate picture by electing four new trustees. They are Gordon S. Brown, head of the Elec-


Recording Unit for Variable 1
Recording Unit for Variable 2
Controlling Unit for Variable 1
Controlling Unit for Variable 2
Units added to Recorder-Controller as needed

Bailey Recorder is key to "step-by-step" automation

When you are pioneering a new process and don't know all the answers, complete automation is seldom practical. The first step is to identify your variables and measure them. Nothing does this job better than a Bailey Recorder. One instrument can record any four variables that can be converted to electric *or* pneumatic signals.

Once you get a better understanding of the variables in your process, you will want to add controls and feed back your measurements. Here's where the versatility of the Bailey Recorder comes into play. For the same Bailey instrument you use to record variables is designed to accommodate plug-in control units.

When you use a Bailey Recorder, you can build your instrumentation along with your process. At the start, you use only the plug-in units for recording. Then you add plug-in controls as you see the need for them.

For the complete story of how you can use a Bailey Recorder for step-by-step automation, see your Bailey Engineer. G-42-1

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BAILEY METERS

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ACTUAL SIZE

STRAPONS, developed by Arthur C. Ruge Associates Inc., answer the need for a moisture resistant, portable, reusable and truly flexible surface temperature transducer.

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In addition to RdF STRAPONS and standard STIKONS, we manufacture a wide variety of special elements and systems for temperature measurement and control. Send for free literature or write stating your special problem.

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HOB

WHAT'S NEW

trical Engineering Dept. of MIT; W. W. Garey, publisher of CONTROL ENGINEERING; Cuthbert C. Hurd, director of automation research at IBM, and Augustus B. Kinzel, vice-president for research at Union Carbide Corp. These men bring the number of trustees to 14, five others having been elected since the initial FIER meeting in New York in December (CtE, Feb., p. 32).

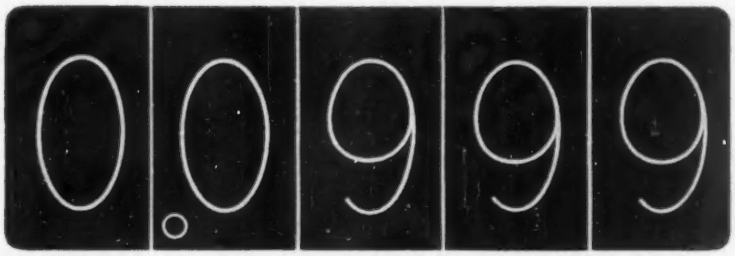
C. B. Hurd

A. B. Kinzel

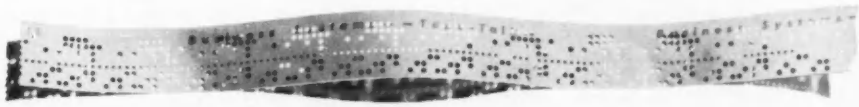
The five are: A. V. Austin, director of the National Bureau of Standards; R. Burnstan, president of Borg-Warner Corp.; H. F. Colvin, president of Consolidated Electrodynamics Corp.; A. F. Sperry, president of Panellit, Inc., and Heller. Other changes since the item in the February issue: Rexford A. Bristol of The Foxboro Co., who was listed as temporary chairman of the board, is now president of the foundation; Charles B. Jolliffe of RCA Laboratories, then a director, has moved up to vice-president, and Lloyd E. Slater, former managing editor of CONTROL ENGINEERING, has officially taken up his duties as FIER executive director.

• **FIER fellowship**—Another development that preceded the Ridgefield clinic was approval of a second project for the foundation. This one was submitted by board member William H. Kushnick, executive director of the ISA, the group that got FIER under way with an initial grant of $4,000. It involves a $2,500 graduate fellowship in control engineering. The work will be done at Case Institute, because, says FIER, "Case has been building in the past seven years, under the direction of Prof. Donald P. Eckman, an extensive and comprehensive graduate program in control engineering. Its emphasis on process control is considered by many as second to none."

Presentation of the fellowship will be made at the annual meeting of the ISA in Cleveland this September. Case, whose Committee on Graduate Study will make the choice, will receive $1,500 from ISA for full graduate tuition and other expenses.

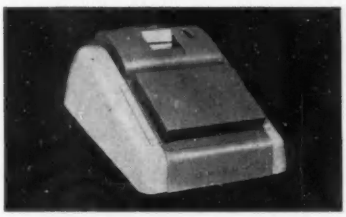


EITHER WAY OR BOTH

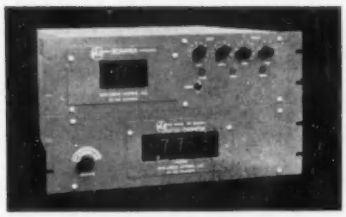


...in a clear numerical form or a printed record NLS gives you rapid, accurate electrical measurements.

The vital accuracy in electrical measurement instruments that today's exacting sciences demand is provided by Non-Linear Systems, Inc. Not only are NLS digital instruments unsurpassed in speed, dependability and long life, but their visual readout performance may be supplemented by printed data recorders. Thus, visual reading may be done by unskilled personnel while printed or punched paper data is also recorded for future study. Complete, pre-engineered automatic test systems can be established by adding input scanners to NLS digital instruments, permitting sampling of up to one thousand stations. Oil immersed stepping switches – an exclusive NLS feature – assure constant accuracy and trouble-free long life of both NLS digital voltmeters and ohmmeters. The NLS line of digital instruments covers a wide range of engineering and scientific electrical measurement applications. Whatever your needs in this field, NLS can meet your most exacting requirements in instruments and systems. Your inquiry will be welcomed.



Clary Printers (both 8 column and 11 column) are supplied by NLS to be used in connection with DC digital voltmeters, 4 digit and 5 digit AC/DC voltmeters or ohmmeters.



Input scanners used with NLS digital voltmeters or digital ohmmeters provide for automatic scanning of many inputs and when used with data recorders provide complete automatic systems.

Flexowriter equipment for typewriting of data and simultaneous paper tape punching may be used with NLS digital voltmeters and ohmmeters. NLS Flexowriter converters are provided for this purpose.

Originators of the Digital Voltmeter

NLS non-linear systems, inc.

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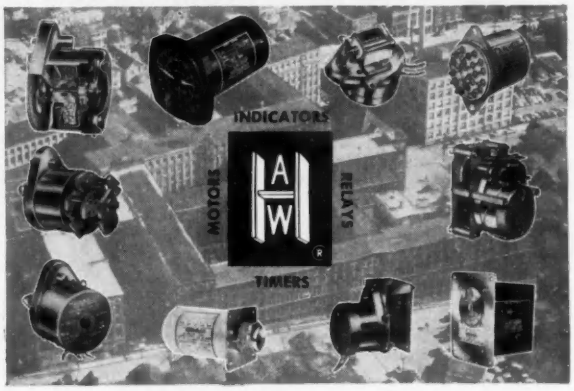
Digital Ohmmeters • AC-DC Converters • Data Reduction Systems • Digital Readouts
Peak Reader Systems • Binary Decimal Converters • Digital Recording Systems

one source for all timers!

the
A. W. HAYDON COMPANY *offers a*
COMPLETE LINE *of* **STANDARD** *and* **CUSTOM DESIGNED TIMING MOTORS** *and* **DEVICES!**

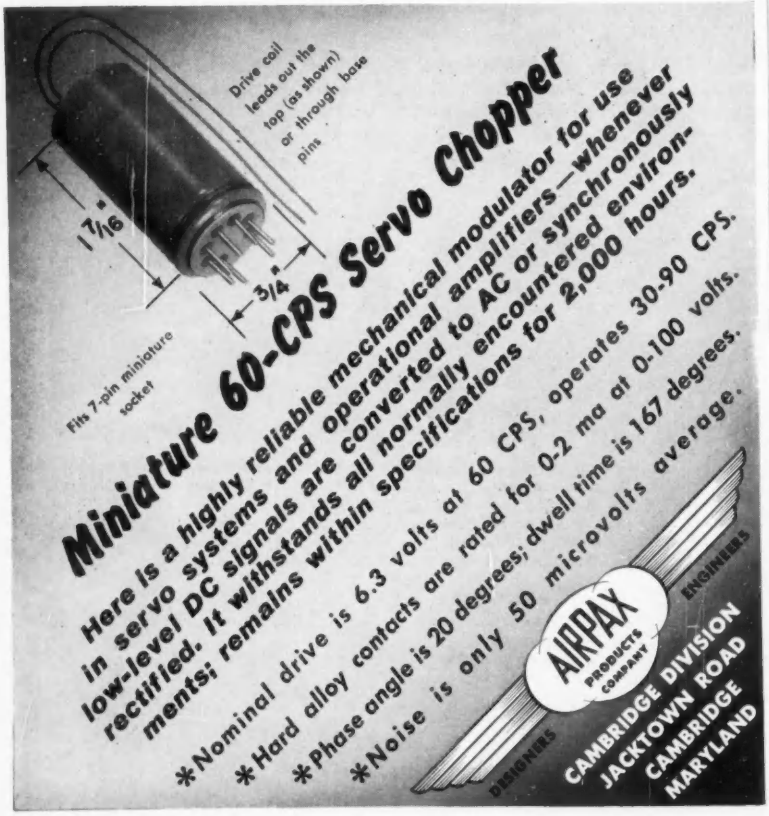
for military and industrial applications. Illustrated are some of these units . . . any can be modified to meet your specific requirements if the basic design is not adequate.



Shown below is the new catalog of the A. W. Haydon Company describing all of the basic types of units available and many of the "specials". Included in this 25-page catalog are 60 photographs of timers, 30 dimensional drawings, and 50 charts and diagrams. This complete catalog will be supplied on request.

- Long a pioneer in the timing field, The A. W. Haydon Company is prepared to assist you in solving your timing and control problems. When a solution to your problem has been reached, The A. W. Haydon Company is prepared to follow through with production geared to meet your requirements whether a basic timing unit or a highly specialized device is required.

the **A. W. HAYDON COMPANY**
246 NORTH ELM STREET
WATERBURY 20, CONNECTICUT
Design and Manufacture of Electro-Mechanical Timing Devices


Drive coil leads out the top (as shown) or through base pins
7/16"
3/4"
Fits 7-pin miniature socket
Miniature 60-CPS Servo Chopper
Here is a highly reliable mechanical modulator for use in servo systems and operational amplifiers—whenever low-level DC signals are converted to AC or synchronously rectified. It withstands all normally encountered environments; remains within specifications for 2,000 hours.
*Nominal drive is 6.3 volts at 60 CPS, operates 30-90 CPS.
*Hard alloy contacts are rated for 0-2 ma at 0-100 volts.
*Phase angle is 20 degrees; dwell time is 167 degrees.
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WHAT'S NEW

IRE Regional Woes

Poor turnout by trade-show standards makes ambitious San Diego conclave a questionable success.

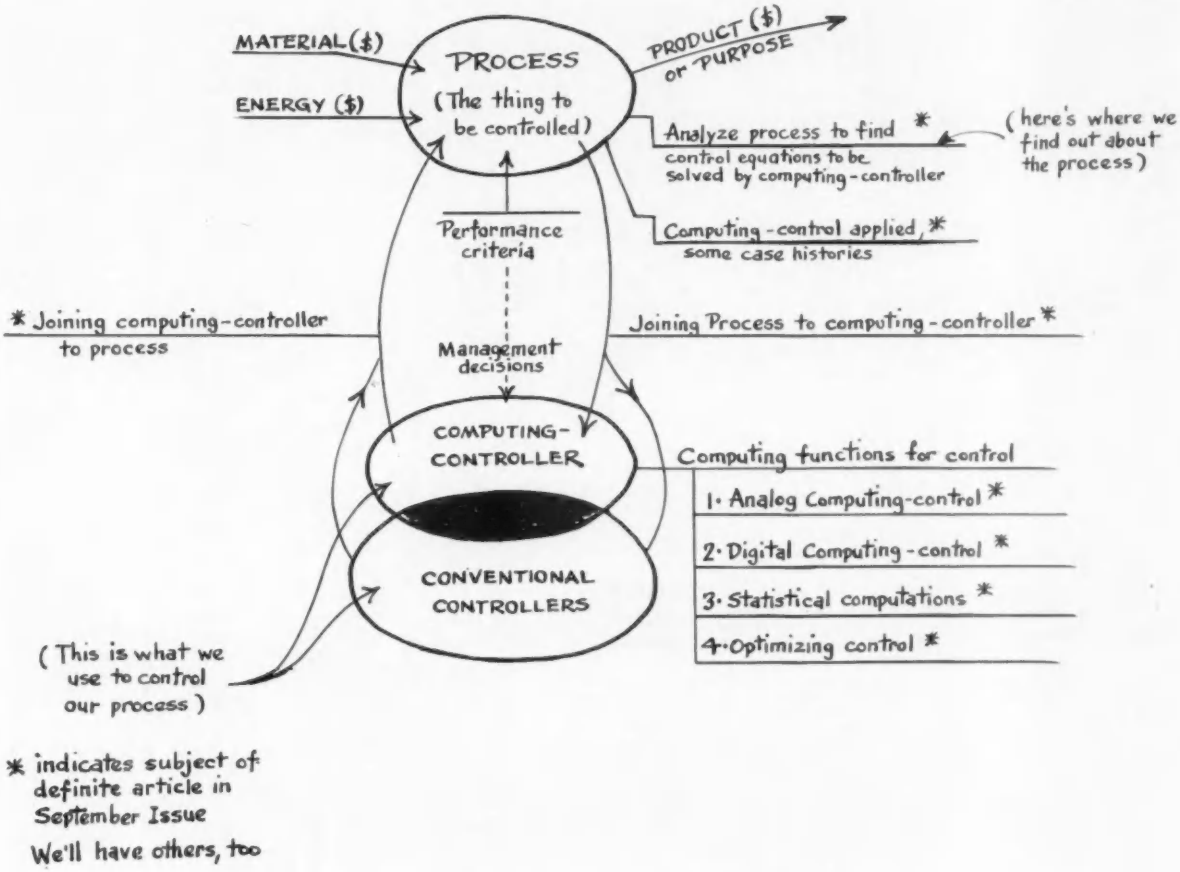
The Seventh Region IRE Conference at San Diego April 24-26 was marked by most of the signs of a successful meeting—good attendance (from the point of view of the program planners), excellent papers, and a lot of enthusiasm—and yet it could not get out from under the curse of the local conclave: money trouble. As far as the conference officials were concerned, the 3,000 engineers who came cut a striking figure, but for the show people, they weren't enough.

Another story in this news section tells how the ISA made a try at tacking on a trade show to a national meeting in Los Angeles, dangling over the head of its National Flight Test Instrumentation Symposium the threat of regional status if it didn't acquiesce. The symposium held out successfully, and in doing so pointed up what seems to be a current dilemma for all technical societies: to hold or not to hold a trade show with their meetings.

• **Horns of the dilemma**—On the one hand, an IRE regional, faced with the problem of paying for a meeting and at the same time keeping admission fees reasonable, invites exhibitors, only to hear that resulting sales leads are disappointing and the manufacturers dissatisfied. This particular IRE regional has gone ahead to explore methods for subsidizing its conference, with a view toward eliminating exhibits altogether as a supporting element. On the other hand, an ISA national meeting, probably faced with similar financial troubles, is asked to accommodate a trade show and bluntly refuses to do so. The obvious questions: why is a trade show preferred in some cases, why is it scorned in others, and is it really necessary for holding down the cost of admission?

The conference at San Diego was an ambitious undertaking. Chairman Robert E. Honer, Convair-San Diego, said it was the largest technical meeting and trade show ever staged by a regional IRE group, this despite the grumblings by the manufacturers. Sessions were devoted to instrumentation, data handling and automation, the International Geophysical Year, nuclear activity and damage, and electronic aids to navigation. Control

Functional Diagram of Control Engineering's Sept. 1957 Issue


MATERIAL ($)
ENERGY ($)
PROCESS
(The thing to be controlled)
PRODUCT ($) or PURPOSE
Analyze process to find * control equations to be solved by computing-controller
(here's where we find out about the process)
Performance criteria
Computing-control applied, * some case histories
* Joining computing-controller to process
Management decisions
Joining Process to computing-controller *
COMPUTING-CONTROLLER
Computing functions for control
1. Analog Computing-control *
2. Digital Computing-control *
3. Statistical computations *
4. Optimizing control *
CONVENTIONAL CONTROLLERS
(This is what we use to control our process)

* indicates subject of definite article in September Issue

We'll have others, too

Coming . . . in September Control Engineering

an entire issue devoted to the specifics of

"COMPUTING CONTROL"

Progress in this science we are so deeply and happily involved in, has been startling. But with progress, *new problems.* As control systems get closer and closer to optimum operation, previously unrecognized limitations in some other aspect of measurement and control rear their ugly heads . . .

So, you see, it's a natural step from the broad scope of last September's *"How to Follow the Steps in Control Systems Engineering"* to September, 1957, and the specifics of *"Computing Control"* . . . . a timely, practical approach of major concern to control engineers everywhere. You will be interested, regardless of what process you work with—be it missile or machinery, petroleum or packaging.

The loop illustrating this message, as roughed on the back of an old paper bag by Associate Editor Harry Karp, gives you the sense and "system" for the issue. Here, further, to whet your appetite, is a fast rundown on what to anticipate:

Editorial Outline

I. How Computing Controllers Can Upgrade Your Process
II. Computing-Control Applied (5-6 articles)
III. Establishing the Control Problem for the Computing-Controller to Solve
IV. Analog Computing-Control
V. Digital Computing-Control
VI. Joining the Process to the Computing-Controller
VII. Joining the Computing-Controller to the Process
VIII. Statistical Computation for Control
IX. Optimizing Computing Control

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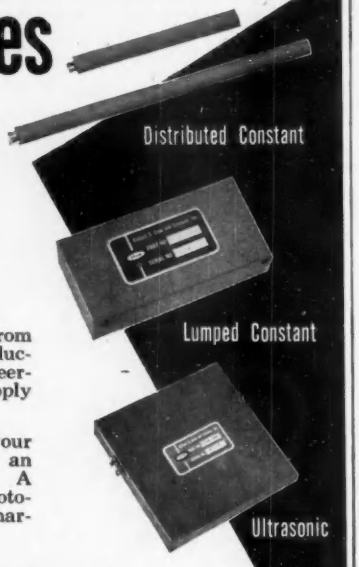

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WHAT'S NEW

men seemed to be most interested in the first two categories.

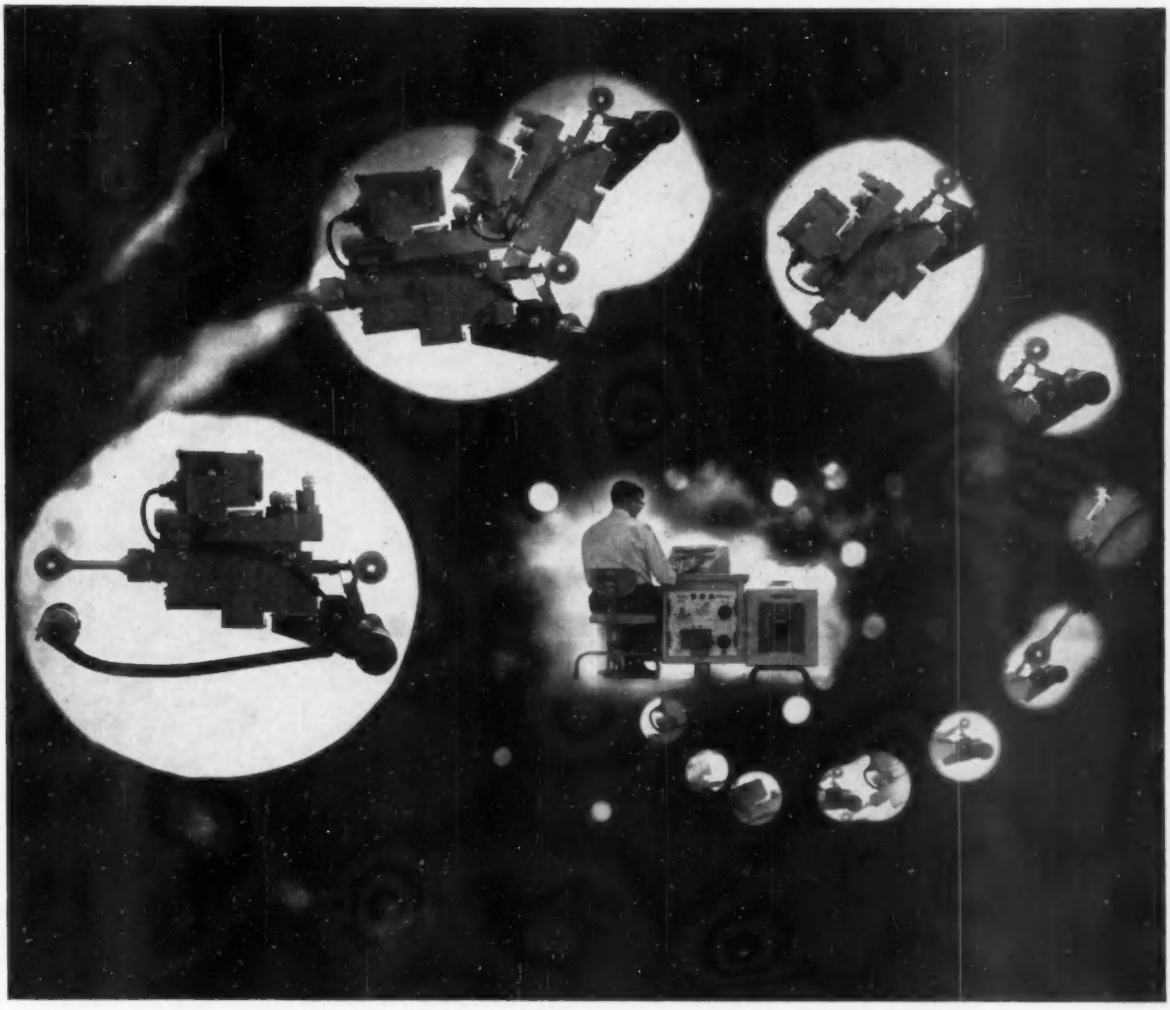
• **Instrumentation papers**—R. W. Rutishauser of Litton Industries kicked off the instrumentation session with a paper describing the examination of design networks with time varying coefficients by means of a Litton 20 Digital Differential Analyzer. One of his conclusions was that transducers with ac excitation have limited dynamic usefulness. After Rutishauser came J. R. Wood of North American Aviation with a paper on "Sound Pressure Instrumentation of Rocket Engines", William Kneen of Consolidated Electrodynamics with one on "Millisadic and Its Applications to the Processing of Commutated PDM and PAM Data", and finally M. J. Mendelson of Norden-Ketay, who spoke about "A Special-Purpose Arithmetic Unit for an In-Line Processor".

Mendelson dealt with the logical design and the arithmetic and digital techniques for a special-purpose computer for scaling, calibrating, and translating digital data. He explained how the arithmetic used in floating-point binary is presented to the device in minimal time by factoring, shifting, and pattern recognition.

• **System dynamics vague**—Speakers at the session on data handling and automation concluded that not enough is known about systems dynamics to effectively use computers in real-time control. They suggested letting the computer provide inputs to the control system while minor-loop controllers control the variables.

In the only evening meeting held, David Packard of Hewlett-Packard Co. told a panel on professional management how his company has financed its growth solely through company profits. It was an interesting presentation. What could have been just as interesting in its own way, but turned out to be not too sensational, was the afternoon talk by O. D. McCoy of Collins Radio Co. on "Collision Avoidance Systems". He disappointed his audience by not taking up Collins' abandonment of collision-avoidance hardware except to say that Collins came to realize such devices are premature. He did suggest, however, that a collision-avoidance system is a fast-approaching possibility.

Among the big exhibitors at the trade show were RCA, which displayed its weather-avoidance radar and its new AVQ-60 transponder beacon, and Hughes Aircraft, with its Falcon missile and a model of the Convair F-102 which is Falcon-armed.



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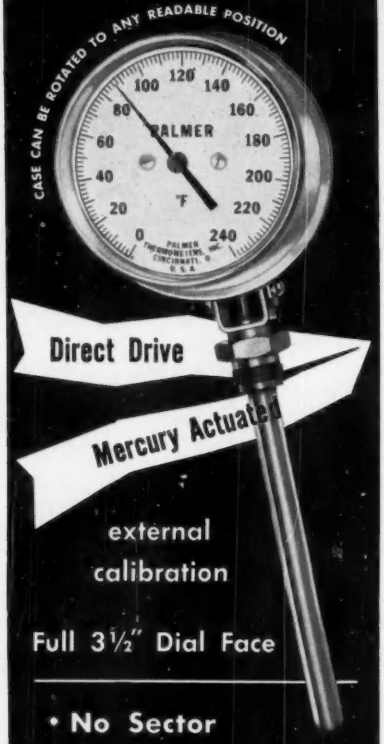

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AROUND THE BUSINESS LOOP

Merger with NCR Off, but Underwood's Eyes Still Open

Underwood Corp. might still have plans to go into business with another company, but there's no longer any talk of the other company being The National Cash Register Co. Just when a merger of Underwood and NCR had reached the stage of probability (CtE, May, p. 48), discussions were terminated by mutual consent. That does not mean Underwood has stopped looking around, company officials say, but they add that any future talks would have to involve the sale of Underwood shares at a price well above the current market. They made special note of the fact that the company ended a 14-month losing streak last March by recording a "modest" operating profit, and predicted a satisfactory profit for the rest of the year if present forecasts are fulfilled.

Electrical Makers Step Up Semiconductor Education

The National Electrical Manufacturers Association has stepped up efforts to keep industry informed about developments in the field of semiconductors. Since 1948 the association's Semiconductor Rectifier Section has been busy standardizing components and equipment, making statistical and market analyses, and taking an active part in the International Electrotechnical Commission. Now NEMA has formed a special informational committee on semiconductors, which will supplement this work by educating industry and the public to the various services of the association and to the benefits to be derived from activity in it. Companies represented on the committee are: Westinghouse Electric Corp., Schauer Mfg. Corp., General Electric Co., Fansteel Metallurgical Corp., and Radio Receptor Co.

Clevite Joins Case Study, Gives It a Control Flavoring

Clevite Corp. has joined Case Institute's Industrial Nuclear Center Study Group, giving the group its first representative specifically devoted to control engineering and raising the number of participants to seven. Like the other companies in the group, Clevite supports its own vigorous R&D program in nucleonics. This includes development of new materials for reactor components, methods for fabricating these components and for producing tailored metallic and ceramic structures, and research under contract for companies in the atomic field.

The study group is considering building a center that would include a high flux engineering test reactor and associated equipment, and facilities for educating and training personnel in applying nuclear science concepts to industrial processes.

New Beckman Division Opens: Another on Way

Beckman Instruments, Inc., has whipped a new division into shape in its breeding grounds in Fullerton, Calif., and has still another one in the works. Ready to go is the Process Instruments Div., which will be headquartered at Fullerton under former scientific instrument sales manager Mark H. Howlett, and still to come is a Systems Div., to be under the supervision of John F. Bishop, formerly manager of the Scientific Instruments Div. Bishop's promotion gives him broad, general-manager responsibilities for four divisions in all: the two new ones, Process Instruments and Systems, and two estabilshed ones, Scientific Instruments and Berkeley. His successor in Scientific Instruments is Thomas V. Parke, formerly manager of laboratory instrument research.

Other New Divisions

A new Shepard Instrument Div for **Savage Industries, Inc.**, of Phoenix, Ariz. Manager and chief development engineer is Edward S. Shepard Sr., a former AiResearch man and a consistent contributor to CtE (his most recent article was in the June issue, page 143). His division will specialize in telemetric data systems.

An Industrial Products Div. for **International Telephone & Telegraph Corp.**, in the Clifton, N. J., home office. Division president Joseph A. Frabutt will continue as general manager of the division's West Coast aircraft products plant. Other officers are: Rudolf Feldt, vice-president and manager of instruments, and L. J. Heilman, Ralph

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Personnel Inquiries Invited

WHAT'S NEW

Lehman, and David Monro, managers, respectively, of railroad and mobile equipment, commercial aviation products, and airborne integrated power supply operations.

An R&D facility for **Topp Industries'** San Diego laboratories, in Solana Beach, Calif., to specialize in guided missiles, electronic systems, and subsystems for advanced aircraft. In charge is Benjamin R. Gardner Jr., formerly design engineer at Convair and before that president of Techniques, Inc.

A research and engineering group in **Microwave Associates, Inc.,** for "the study and improvement of highpower microwave switching devices". Division chief Lawrence Gould and his 10 engineers and physicists are currently involved in problems posed by the tremendous power outputs of advanced magnetrons in the new radar systems.

A Spectron Div. in **Consolidated Electrodynamics Corp.,** to design and manufacture optical systems for missiles and instrumentation, develop mirrors, lenses, and prisms for several Consolidated products, and in general cover the precision-optics field. Russell L. Kiernan, formerly with Texas Instruments, Inc., is in charge of the new division, which, according to President Hugh F. Colvin, was set up in answer to a growing need for high-quality optics in instrumentation. Its 30-man staff has moved into a new, 16,000-sq-ft building in Monrovia, Calif.

A Vacuum Film Products Div. in **Servomechanisms, Inc.** at El Segundo, Calif., to specialize in high-temperature miniaturized circuit components utilizing vacuum-film deposition techniques. David W. Moore is manager.

A Contract Engineering Dept. in **Beckman Instruments'** Helipot Div., to develop electromechanical subsystems for aircraft, missiles, and industrial-plant-control equipment. Frederick Marsh, formerly chief customer engineer, will pilot the new arm.

A Specon Products Section in the Stratos Div. of **Fairchild Engine & Airplane Corp.** at West Babylon, N. Y. Establishment of the new section, the former Speed Control Div. headquartered at St. Augustine, Fla., is in line with a company move to consolidate all industrial activities in speed control and pneumatics into a single operation. The section's variable-speed transmissions, differentials, and other devices will carry the "Specon" tradename. General manager of Stratos is F. E. Newbold Jr., a Fairchild vice-president.

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IMPORTANT MOVES BY KEY PEOPLE

Welch Succeeds Dever as President of SAMA

Richard E. Welch, vice-president and treasurer of W. M. Welch Mfg. Co., has been elected president of Scientific Apparatus Makers Association, succeeding Henry R. Dever, president of Minneapolis-Honeywell's Brown Instruments Div., in the two-year past. New president pro tempore is G. A. Downsbrough, president of Boonton Radio Corp. Others elected at the recent White Sulphur Springs meeting: A. G. Dixon, president of International Equipment Co., and Erik L. Sjostrom, president of John E. Sjostrom Co., section chairmen of laboratory apparatus and laboratory equipment, respectively; and Ray G. Halveren, executive vice-president of Hamilton Mfg. Co.; Earl R Mellen, president of Western Electrical Instrument Corp., and Dever, directors at large.

Other Important Moves

▶The new head of the advanced research section in the Product Development Dept. of National Cash Register Co.'s Electronics Div. is **John W. Young Jr.**, a former mathematics instructor who has taught at the University of Pennsylvania and the University of Delaware.

▶A noted mathematician has been named manager of the Information Processing Div. in the research development branch of Lockheed Aircraft Corp.'s Missile Systems Div. He is **John P. Nash,** most recently research professor of applied mathematics in the University of Illinois. Before that he was research physicist with Kimberly-Clark Corp. and a staff member of the Radiation Laboratory of MIT. At Lockheed Nash will supervise the departments of mathematics and computer services, logical design, and equipment development.

▶**Heinz Fornoff** has been appointed vice-president for engineering by Specialities, Inc., which acquired him from Sperry Gyroscope's Drone & Missile Flight Control Dept. Before taking over this department, Fornoff was with Wright-Patterson AFB, first as a specialist in autopilot evaluation and later as a project engineer on remote flight control equipment for drones. He came to the U. S. in 1946 from Germany, where he managed a plant making airborne control equipment.

▶The election of **Clifton T. Foss** as vice-president of American Bosch Arma Corp. has set off a series of

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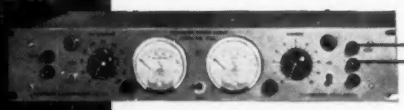

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WHAT'S NEW

changes in the company's Arma and Chicago divisions. The results: **E. D. Gittens,** formerly vice-president for engineering in the Arma Div., replaces Foss as vice-president and manager of that division; **Ernest M. Riggleman,** manager of the Chicago Div., takes on additional duties as vice-president; **Wilford L. Larson,** most recently assistant to the vice-president for operations at the Dunkirk plant of American Locomotive Co., becomes vice-president and assistant manager of the Arma Div., and **Ernest A. Goetz** advances from assistant chief engineer to chief engineer of the Arma Div.

Foss, with the company since 1933, has been successively head of R&D, assistant chief engineer, and vice-president for engineering; Gittens, there since 1935, stepped up to his most recent position from vice-president and chief engineer; Riggleman has had 34 years with Studebaker; Larson has been with Convair and Gar Wood, among other compaines.

▶The new chief engineer of Topp Mfg. Co. is **Robert L. Baddorf,** most recently chief engineer and works manager of Servomechanisms' Mechponents Div. He has also been chief engineer and general manager of Alectro, Inc., and assistant professor of engineering in the University of Southern California. While at the university he headed the Electronics & Instrumentation Group in the Engineering Center. He is author of the college text, *Electronic Laboratory Guide.*

▶**Frederick A. Schaner** leaves Air Associates, Inc., where he has been manager of the Receiver Engineering, Research & Development Div., to go to The Daven Co. as chief engineer. A senior member of the IRE, Schaner has done R & D work on subminiature tuned receivers for aircraft and missile data link systems.

▶**Babbo Ram Teree,** who just recently became chief engineer and manager of engineering and manufacturing of Greer Hydraulics, Inc., has moved up again, this time to vice-president for engineering and manufacturing. His past activities were detailed in the December '56 issue, page 160.

▶Another new chief engineer is **Glen E. McClure,** who takes the post at Electromation Co. An important man in the fields of radio frequency and ultra-high frequency, McClure designed the r-f elements for the "TACAN" portable beacon simulator while he was with Hoffman Labora-

tories. He has also been with Schwein Engineering Co. as chief electrical engineer.

▶Ford Instrument Co. has chosen **Edward C. Wagner** to fill a new post, that of assistant to the vice-president for engineering, and has named **Michael A. Moscarello,** formerly head of the Engineering Dept., to succeed

E. C. Wagner

M. A. Moscarello

Wagner as engineering director for marine equipment. Moscarello's new responsibilities will cover projects in gunfire control and rocket and missile launching computers. Wagner has been with Ford since 1933, Moscarello since 1951.

▶Texas Instruments, Inc., has formed a new engineering branch for applications and test equipment in its Semiconductor-Components Div. and has named **Robert L. Trent,** an authority on electronic circuit development, to direct it. A co-winner of the 1957 W. R. G. Baker Award, Trent has done patented work on transistor switching circuits and feedback amplifiers, most of it with Bell Laboratories, Inc., where he was employed for 16 years. His new division will concentrate on basic circuit research, studies of nonlinear switching circuits and characteristics of power output devices, and high-frequency applications.

▶New presidents have been elected by several control companies. Among them: **Walter H. Sieger,** who succeeds **A. Thomas Ball Jr.** at Revere Corp. of America; **Philip A. Sprague,** who takes over at The Hays Corp. (his new executive VP is **Donald R. Schoen); James F. Connaughton,** a former vice-president of Baldwin-Lima-Hamilton, who advances from executive vice-president at Sterling Precision Corp.; **John Carter,** formerly vice-president of Corning Glass Works, who, at 37, takes the top-level job at Fairchild Camera & Instrument Corp., succeeding **John H. Clough,** recently resigned; **George Tooby,** a former consulting engineer, named by Computer Engineering Associates; and former Army Secretary and Budget Director **Frank Pace Jr.,** who moves up from vice-chairman of General Dynamics Corp. (his new executive VP is **Earl D. Johnson,** a former Army under-secretary, who most recently was senior vice-president for operations and fiscal affairs).

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What Research Means to American Business

American industry plans to invest $150 billion in new plant and equipment during the next four years—more than in the five years 1952-1956. It plans to carry out this record investment even though manufacturing capacity has nearly doubled since World War II. These facts are reported in McGraw-Hill's tenth annual survey of Business' Plans for New Plants and Equipment. They contradict many long-established theories about investment in capital goods.

According to the textbooks, a high and rising level of capital investment is generally followed by a decline. The bigger the rise—so the old theory goes—the bigger the decline will be. But, after a decade of high-level investment and an especially strong rise in the past two years, industry now has plans to keep right on with near-record outlays for plant and equipment. Does this mean some new factor has been added, to change the investment cycle?

The New Factor—Research

The latest McGraw-Hill survey points out one new factor which, more than any other, is changing the nature of the investment process. This is the record outlay planned by U.S. corporations for **scientific research and development**—to create new products and develop new industrial processes. The rapid growth of research in industry, and plans for even more remarkable growth in the years ahead, are shown by the accompanying table.

This year industry plans to spend $7 billion on research and development—up 20% from 1956. By 1960 it will spend $9 billion—enough to create a major new industry.

By 1960 manufacturing industry expects sales to be up 26%—with half the increase in products that were not made in 1956.

Growth of Research and Development Expenditures

(Millions of Dollars)

			PLANNED	
	1955	1956	1957	1960
Machinery	408	506	577	704
Electrical Equipment	950	1,149	1,310	1,637
Aircraft and Parts	1,038	1,558	2,274	3,161
Fabricated Metal Products and Ordnance	134	165	174	210
Professional and Scientific Instruments	185	252	300	453
Chemicals	440	498	528	617
Paper, Rubber, Stone, Clay and Glass Products	149	174	196	233
Petroleum Products	171	205	225	277
Other Manufacturing	1,038	1,279	1,388	1,557
Non-manufacturing industries	254	310	347	419
ALL INDUSTRIES	4,767	6,096	7,319	9,269

What Research Is Doing

Here are some examples of how industrial research is opening up new markets, or compelling the modernization of old facilities:

New automatic controls in petroleum refining will raise the quality of gasoline and reduce the time required for production. A new process for recovering oil from depleted wells promises to multiply our potential reserves.

A new process for treating iron ore will permit the ore to be fed directly into steel furnaces—without the need for blast furnaces or coke ovens.

New turbine engines—made possible by the development of heat-resistant alloys for turbine parts—offer greatly increased power for aircraft, ships and automobiles.

Altogether, industry plans to introduce more new products in 1957-1960 than in any previous four-year period. It also plans new processes on a scale that will make much of our present capacity obsolete. These new products and new processes are the secret behind continuing plans for high investment.

One-third of all manufacturing firms are building new plants this year to produce new products, and by 1960 this may account for 10% to 20% of all capital expenditures. At the same time, manufacturing companies report that over half their capital expenditures in the next four years will be for modernization of equipment and introduction of new processes. Thus the preponderant share of new investment will be based on developments growing out of research.

A New Kind of Prosperity

The keen interest of U.S. business firms in scientific research points the way to a new kind of prosperity for our economy—a prosperity based on deliberate creativeness. As long as we can create new products that will offer better value to consumers or cut costs to manufacturing firms, business will continue at a high level—not at fever pitch, perhaps, and it is to be hoped not at an inflationary pitch. But based on a steady stream of new products and processes, we can have a high level of general prosperity that defies the old laws of boom and bust.

It's Not Automatic

Of course, there is no guarantee. New products do not spring up by magic as the medieval alchemists hoped they would. They are found as the result of long and expensive effort in laboratories and pilot plants. This effort requires an increasing number of trained scientists and engineers. In 1957 alone, manufacturing companies report they will need 7% more of these highly trained people in research and development. And by 1960, they will need an additional 15% to carry out planned research programs.

The effort to maintain prosperity — as well as the national defense effort — will depend increasingly on this supply of scientific and technical personnel. But if we can supply the people, industry now has the plans for a research effort that will put an end to the spectre of idle plants and idle workers.

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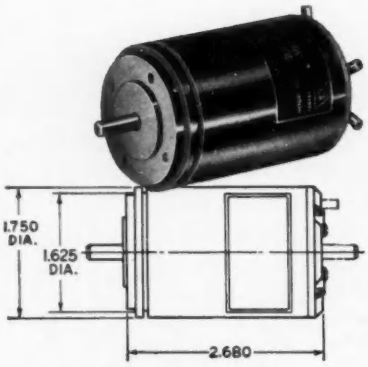

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ABSTRACTS

Newest solid-state devices

From "Progress in Cypak Component Design" by R. A. Clark, Westinghouse Electric Corp. Paper A-5719. Presented at the 21st Annual Machine Electrification Forum sponsored by Westinghouse Electric Corp., Buffalo, N. Y. April 24 & 25, 1957.

Clark describes two new additions to the family of solid-state devices rapidly finding wide application in industry: a load-controlled magnetic output amplifier to electrically actuate solenoids controlling hydraulic or pneumatic fluids; and a new shift register using fewer components to transmit and store a great deal of information serially in a group of in-line stations.

"In the design of a new [load controlled magnetic output] amplifier, the following amplifier characteristics were considered essential: (1) output voltage is to be 95 to 100 percent of nominal voltage for a 10-to-1 load current range; (2) output must not interfere with self-regulated armature velocity; (3) response should be less than six cycles, including electromagnetic device; and (4) plus or minus 10 percent line voltage variation should not be magnified, but reduced."

Load controlled magnetic output amplifier

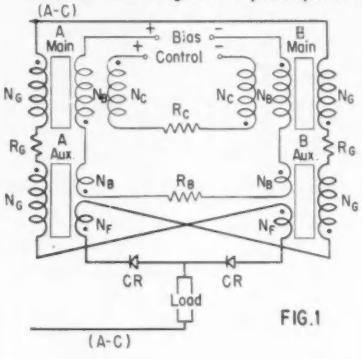


FIG. 1

Figure 1 shows the circuit of the load-controlled magnetic output amplifier, whose two main saturable magnetic cores and two auxiliary saturable magnetic cores, help it meet the above specifications. "The gate windings, N_G, of the main and auxiliary reactors are connected in series and designed so that the combination of both will support the supply voltage when the load is in the off condition. Control signals sufficient to cause saturation are applied only to the main reactors. Load current causes auxiliary reactor saturation for inrush conditions, but bias regains control of the auxiliary cores when load current has fallen to its holding value. The output voltage across the load is, therefore, almost constant for a very wide range of load currents. In other words, the load and the auxiliary reactor divide the supply voltage (minus other circuit drops) so that the load voltage is always between 95 and 100 percent of nominal, approximately."

Figure 2 compares regulation of the new load-controlled magnetic output

A comparison of regulation curves for magnetic output amplifiers

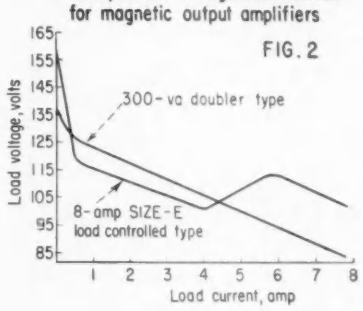


FIG. 2

amplifier with the older doubler-type magnetic output amplifier. It shows the wider range of load currents possible with the new amplifier for typical load voltage variations.

The other new solid-state device is a fewer-component shift register, Figure 3. A typical application for this unit is in warehousing, where a large number of randomly mixed products must be sorted and dispatched to different storage and loading locations. Here each shift register station con-

Shift register block diagram

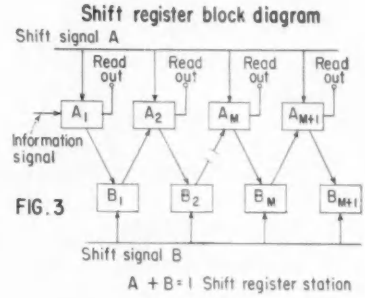
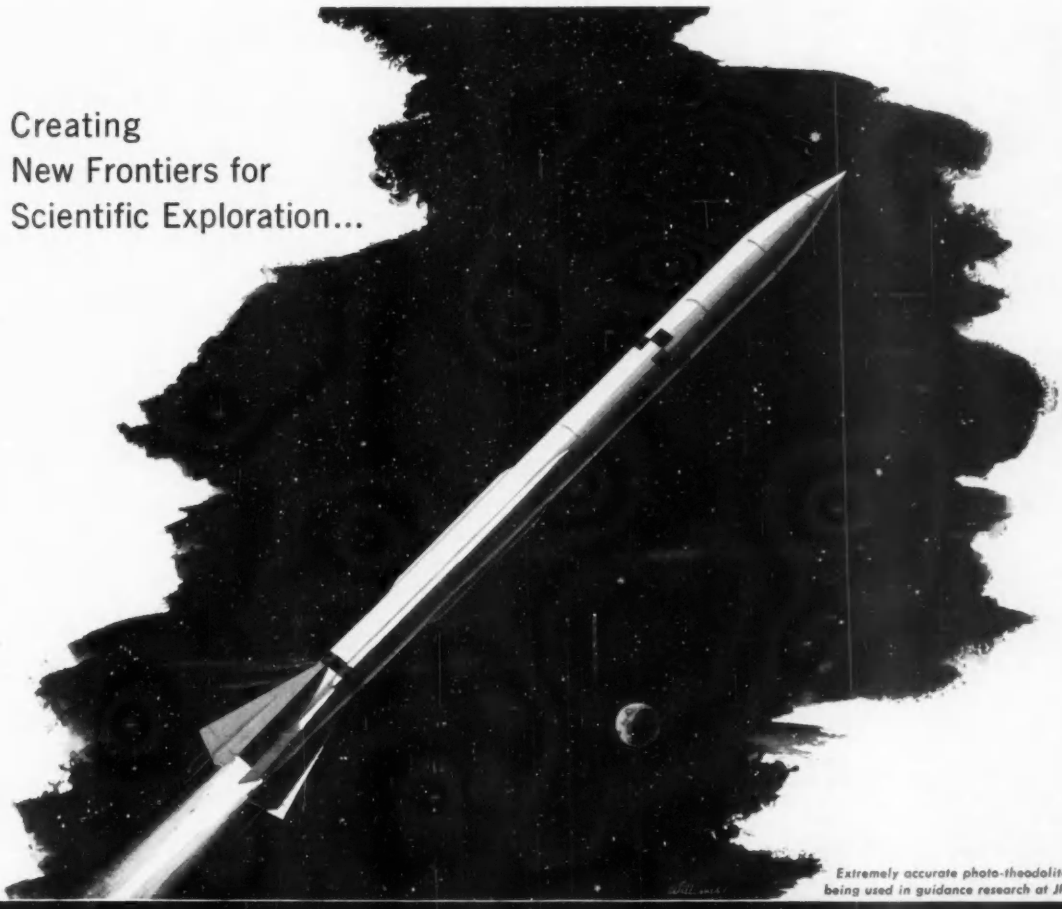


FIG. 3

sists of two standard *NOT* logic modules and two half shift registers (see "Static Switching Devices" by R. A.

Creating New Frontiers for Scientific Exploration...



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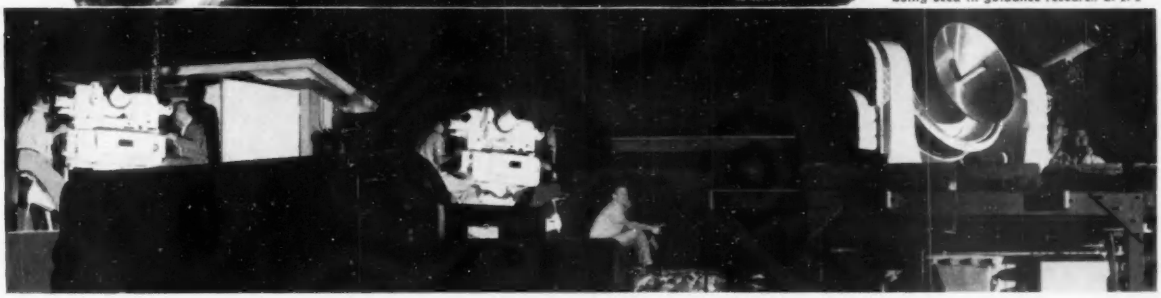

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ABSTRACTS

Mathias, CONTROL ENGINEERING, May 1957).

"Information is received in block A_1. Upon the application of shift signal A the information stored in A_1 is shifted to B_1. The operation also clears A_1 so that it is left free to receive the next bit of information stored in B_1 and A_2. In general, all the information stored in the A_m blocks is shifted to the B_m blocks by the application of the A shift signal. This operation also clears all the A_m blocks so that they may receive further information. Thus, we see that by the use of a binary code, this shift register can store and transmit two pieces of information that is 0 or 1. By the same reasoning, two parallel shift registers can store and transmit four binary-coded pieces of information; that is, 00, 01, 10, or 11. Thus we see that the amount of information storage and transmission is 2^n where n is the number of parallel shift registers."

Diode controls high power

From "The Dynistor Diode, A New Device For Power Control" by A. P. Kruper, Westinghouse Electric Corp. Paper A-5722. Presented at the 21st Annual Machine Tool Electrification Forum sponsored by Westinghouse Electric Corp., Buffalo, N. Y., April 24 & 25, 1957.

Kruper reports on a newcomer in the field of semiconductors—one that has great potential as a static power relay for turning on and off large blocks of electrical power delivered to a load. Still in the development and rating stage, indications are that the Dynistor diode can be triggered by light or radiation, by adding a third terminal making it similar to a thyratron, or by the more common techniques of changing the applied voltage across the load and diode and pulsing with high voltages.

"The electrical characteristics of the diode shown in the figure [page 196], in which certain regions of the curve have been exaggerated for clarity. Note that up to a certain point this device resembles any other diode in that it has a forward and a reverse characteristic. The forward characteristic is not unlike the form one would observe for a conventional diode. However, in the reverse direction the Dynistor diode has two distinctly different regions. The first region again resembles a conventional diode. Starting at zero voltage the saturation current increases very slightly with increasing voltage.

Here G. D. Schott (right), Flight Controls Department head, discusses computer solutions of control and guidance problems with E. V. Stearns (center), Inertial Guidance Department head, and J. E. Sherman, Analog Computer Section head.

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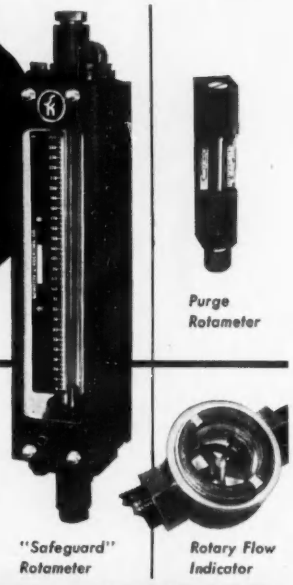

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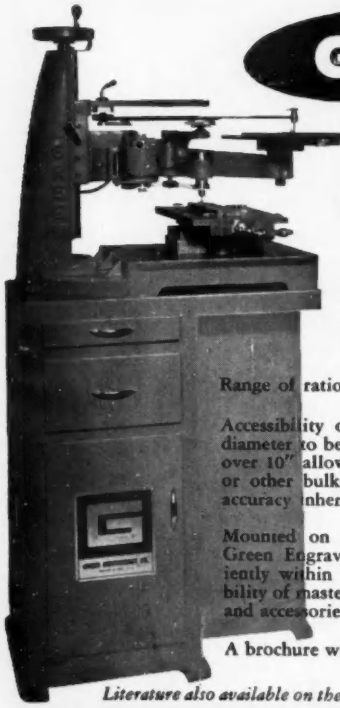

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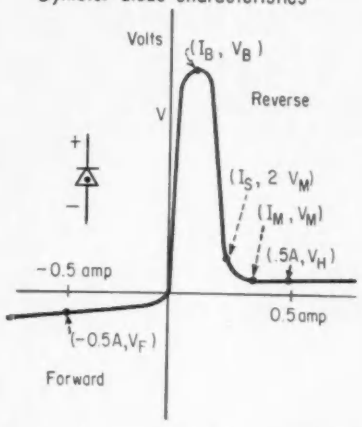
ABSTRACTS

Dynistor diode characteristics



DYNISTOR CHARACTERISTICS

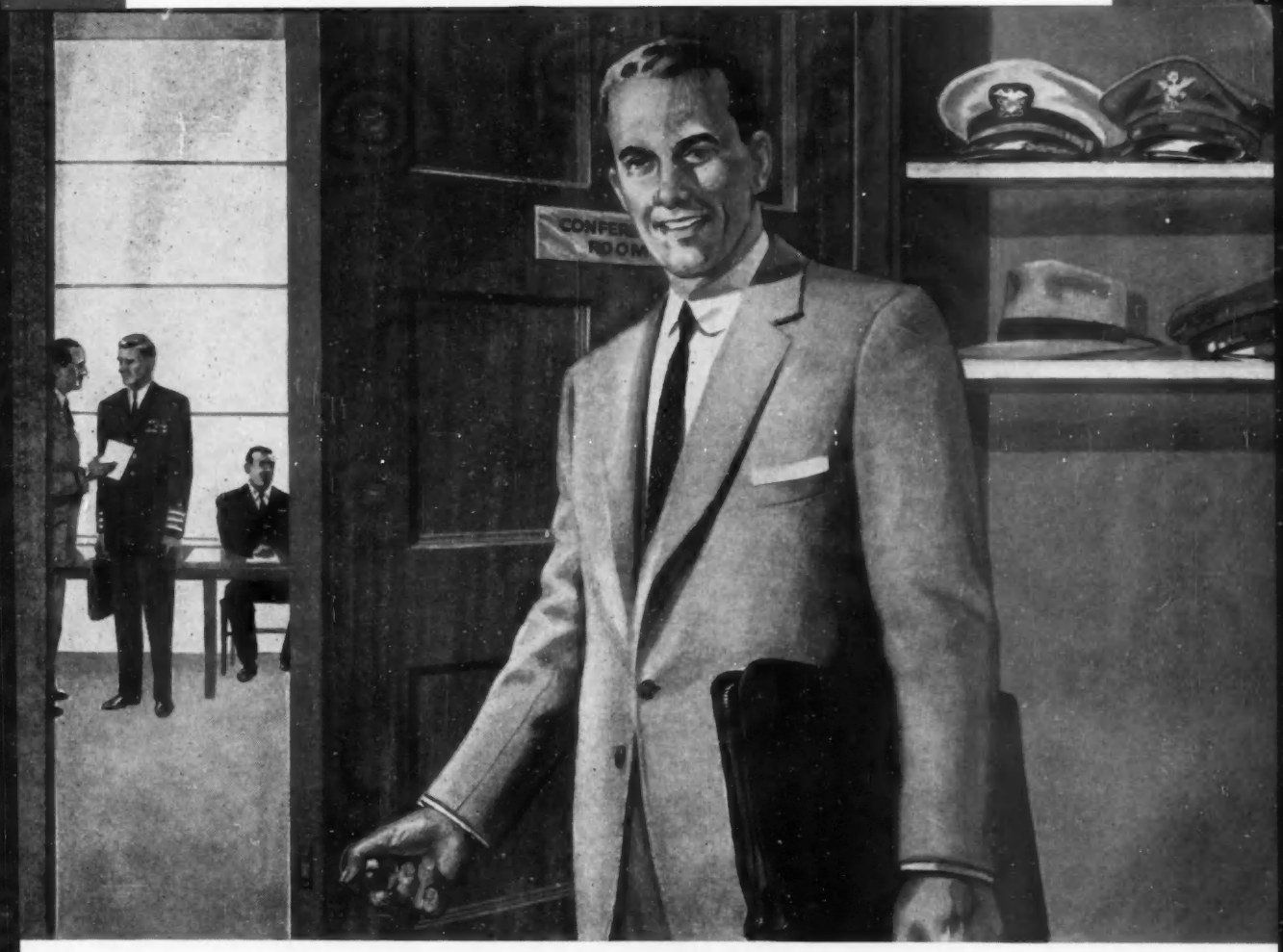
V_B	=Peak voltage ("breakdown" voltage)	30–150 v
I_B	=Current at peak voltage ("breakdown" current)	10 ma
I_S	=Minimum sustaining current (defined at $2V_M$)	10–150 ma
V_M	=Minimum voltage	0.5 v
I_M	=Current at min voltage	100 ma
V_H	=Hyperconductive drop (at 0.5 amp)	0.5 v
V_F	=Forward drop (at −0.5 amp)	1.5–5.0 v
R_H	=Average slope of curve between V_M and V_H	0.3 ohms
R_F	=Slope of curve at $(-0.5, V_F)$	2.0 ohms

The second region begins where the device will no longer support voltage, but breaks down to a very low-value voltage. This second region is composed of two parts, a negative resistance region and a hyperconductive region. The hyperconductive region is characterized by a very-low-resistance value, much lower than in the forward conduction direction."

The table above identifies the symbols used in the figure and also shows a spread of values obtained on germanium diodes.

Not shown on the characteristic curve are the switching times in going to and from blocking and conducting conditions. Turn-on time is less than 0.1 microsec, while the turn-off time is about ten times the turn-on time.

Normally, the voltage across the diode is less than the breakdown voltage, so the device is in the off condition and the applied voltage is across the diode and not across the load. When a voltage exceeding the breakdown voltage is applied, even momentarily, the operating point shifts to the hyperconductive region, turning the device on. Now, the major portion of the applied voltage appears across the load and only a small drop appears across the diode. "To turn the device off, the applied voltage across the de-



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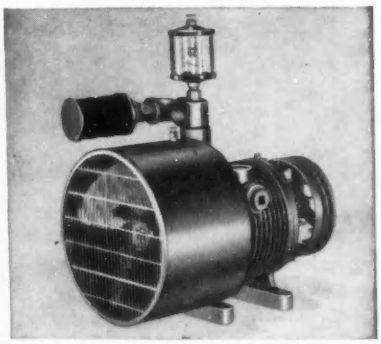

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ABSTRACTS

vice and load is reduced, reducing the load current, until the minimum sustaining current is reached, at which time the device snaps to the blocking or "off" condition."

Although actual power ratings have not yet been established, some units have been operated at 4 amp continuous, and even at as high as 11 amp in special applications. "Under pulsed conditions the units have passed 500 amps in 5 microsec pulses." However, Kruper does not state the ratio of on-time to off-time during pulsing, which is an important factor in determining how hot the diode becomes.

Germanium diodes, for which data are given in the paper, have temperature limitations. Silicon Dynistor diodes, says the author, offer a promise of higher temperature operation.

Self-adaptive control

From "Teleological Control—It Learns by Doing" by A. J. Kerstukos, Westinghouse Electric Corp. Paper A-5710. Presented at the 21st Annual Machine Tool Electrification Forum sponsored by Westinghouse Electric Corp., Buffalo, N. Y., April 24 & 25, 1957.

"Teleological control", states the author, "is a new concept in the field of automatic control. . . A teleological control is allowed to experiment with the process until it finds the goal as determined by a set of built-in rules."

The concept is so new that other workers in the field have not yet arrived at common agreement on a name for it—some call it self-adaptive control and others call it optimizing control. An IRD paper on this subject was presented recently by Columbia University's Rudy Kalman (CtE, May '57, p. 203).

Kerstukos develops the concept of goal-seeking control by starting with simple performance of manual and mental functions. "The manual effort of drilling a hole is distinct from the mental effort of deciding which drill to use. It is one thing to push a lever and another to decide which lever to push. . . . It is always necessary to replace the manual operations of a process by some mechanical device before a substitute for the mental function of the worker can be made." Attaching instruments to processes gives the operator more information for making intelligent decisions. If process information can be expressed

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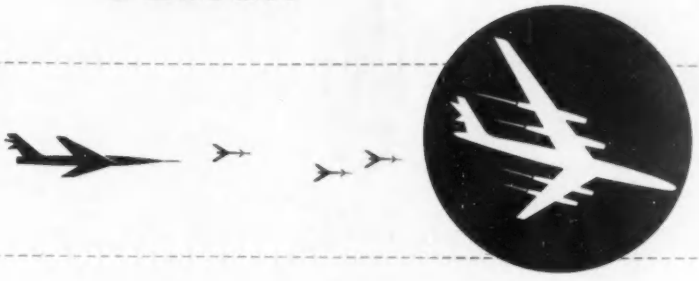

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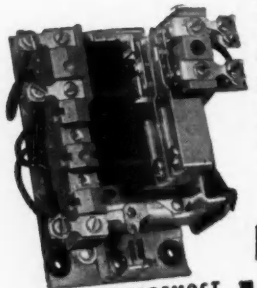

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ABSTRACTS

mathematically and can be predicted and preset into a controller, or can be logically interpreted, the controller can replace some operator functions.

However, contends the author, controllers and computers cannot do original thinking on complicated processes, those whose characteristics are so little understood that existing closed-loop controls do not suffice and proper ones cannot even be built.

"A machine that will control such a process must . . . be able to learn to cope with changing situations, must have the ability to change the input variables with a strategy that will achieve a goal, and maintain stable operation." Such a situation is the one where the output changes with time and its desired value is vague or unknown. Optimum yield is an example.

Westinghouse has developed a teleological control (trademarked Automex, for automatic experimenter) that seeks its goal by intelligent trial and error. It controls a system for optimum output by properly adjusting each of several input variables where the best adjustment for any one input changes with time. At the Machine Tool Electrification Forum Automex was demonstrated by simulating a blind man trying to reach a mountain peak aided only by an audible signal proportional to altitude. He would experimentally try an altitude increment along any of eight different compass directions to find if he went up or down, and, from the best result, proceed on another try until he reached the peak.

In conclusion, Kerstukos points out that the properties of an engineering system can never be known with exactness: it is expensive to test or analyze a process to learn about it; manufacturing operations introduce small differences into supposedly identical products; and wear, fatigue, and drift of conditions change system operation. These drawbacks limit optimum controllability by usual closed-loop controllers. However, teleological or self-adaptive controls offer a new approach to optimum control. They can minimize or maximize the output without knowledge of all variables involved.

Why Students Drop Out

From "Perspectives" by Paul Anderson, "Product Engineering", May 1957, page 123.

"If all the college freshmen who start out as engineers were to graduate as engineers four years later," says

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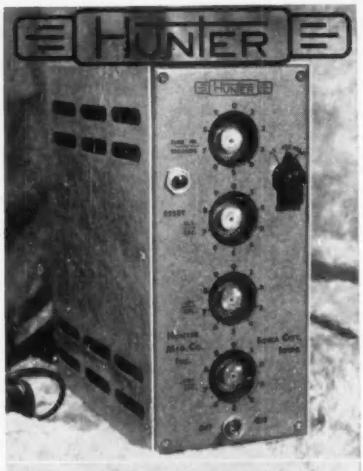

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ABSTRACTS

Anderson, "the present shortage in that field soon would disappear." But this cannot be, he continues, as long as: 1) the difficulty of getting through an engineering course comes as a shock to so many cocky high-school students; 2) the profession is unrealistically glamorized for the college applicant, making him lose interest when he is confronted with the big amount of preparation needed; 3) big-college structures are so designed that there is poor coordination between the technical and liberal arts departments; 4) there is bad preparation in the high schools for college-level technical courses.

There is still a fifth reason for the drop-out problem, and this is the contribution made by the laws that say land-grant colleges must take any and everyone. The national drop-out rate for all engineering schools is 57 percent for four years; for the state universities it is 65 percent or better. But despite this, says Anderson, the state schools are turning out 40 percent of all our engineers at the undergraduate level, and 50 percent of the science PhD's! And this with an enrollment representing only 20 percent of all the college students in the country!

How are they doing it? By fighting back at attrition. In setting up various kinds of freshmen-year housecleaning programs, these schools are saying that just because they can't be selective before registration is no reason why they have to keep the dullards around. But they are not bitter. They are as desirous of doing good by the deserving students as any other kind of school, and in fact sometimes go farther than their private counterparts in trying to "salvage" a willing high-school graduate who cannot be blamed for his own lack of readiness for advanced courses.

The state university in Kansas is an example. In the average Kansas high school "it is not expected that the students have had good math courses because of the lack of competent teachers. But provisions are made in the state university for the student to take noncredit courses in the subject he could not take in high school, and by the second term he is ready to start his college curriculum. Usually a student from a small high school does not do too well in first year in college, but he picks up after that."

Anderson also goes into the pros and cons of the five-year engineering programs, the problem of the engineering-school applicants who "are really technicians at heart", and a few

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ABSTRACTS

other areas, too, in his examination. All in all, his is a fresh approach to a subject that many feel (and rightly) has not provoked anything new for a long, long time.

Humanizing the Loop

From "Automation and Organization" by Maurice Meylon, consultant. Presented at the Congres de l'Automatique, Paris, 1956.

If Dr. Meylon succeeds in putting the theories advanced in this paper into practice, sociologists and psychiatrists will have to brace themselves for new responsibilities. All previous talk about man as a control-system component is whittled down by contrast to childish simplicity by these theories, which attempt to show that the human paper shuffler can be an integral part of an automatic system. Meylon thus links arms with the contingent of machine designers and thinkers who are concerning themselves with the more complex type of electronic computer, the one that processes business (as contrasted to scientific) data. And even here he strides out in front. In theory, anyway.

His idea is that organization (and by this he means the distribution and use of human forces in any business enterprise) can and should adhere to the same laws that govern the machines these humans use, and that govern the economic structure supporting them. It is, to put it mildly, a large undertaking. But Meylon approaches his task with scientific preciseness, first finding an acceptable definition for his word "organization" (to give it equal status with "automation" and "economics"), then drawing up a set of accompanying figures, some of which suggest the familiar closed loop.

Like any other component, Meylon says, man has his variables, and these must be controlled if he is to prove out satisfactorily in any system, especially a system in which he plays the leading role. These variables have to do with his personality, which has "active", "reactive", and "regulative" elements. Since these elements so closely resemble those in machinery, "the psychologist", says Meylon, "who is destined for the organization and is oriented toward the study of administrative mechanisms can no longer be unaware of the principles of the Automatic (sic), and will be, then more and more, a cybernetician."

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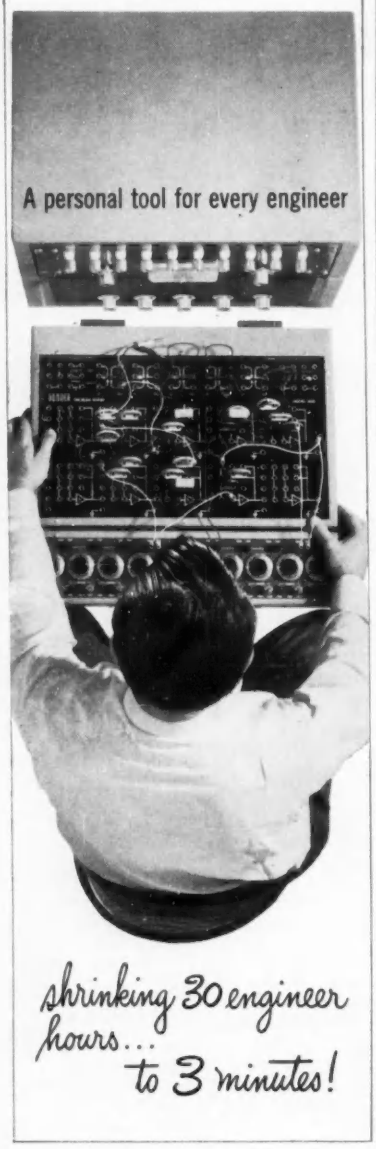

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DIGITAL CALCULATING MACHINES: AND THEIR APPLICATIONS TO SCIENTIFIC AND ENGINEERING WORK. *G. A. Montgomerie. 262 pp. Published by Blackie and Son, Limited, London and Glasgow. 1957. 30 shillings (approx. $5.25).*

Montgomerie emphasizes the efficiency of digital machines in scientific and engineering calculations and those aspects that increase this efficiency. In so doing he treats lightly the history of these machines as well as their adaptation to accounting and other phases of business-data. Details of numerical analysis are avoided.

The text is divided into four parts, the first part covering key-responsive and key-setting adding machines, and hand-, electric-, and automatically-operated four-rule machines that add, subtract, multiply, and divide. Each category is explained in principle and contains a numerical example and references to actual machines.

The other parts cover punched-card, special-purpose, and electronic and universal sequence-controlled machines. Montgomerie points out that special-purpose machines have extended storage capacity for operations but little capacity for numbers—the telephone-relay and multiple-cathode discharge-tube machines are examples. A final chapter takes up the particulars of preparing programs for sequence-controlled machines such as ENIAC, the Harvard Mark I and the Bell Labs relay calculators, and the Ferranti computer.

T. J. Higgins
Madison, Wis.

Dynamic characterizing

PLANT AND PROCESS DYNAMIC CHARACTERISTICS. *Proceedings of a conference sponsored by the Society of Instrument Technology, held at Cambridge (England), April 1956. 246 pp. Published by Academic Press, Inc., New York, and Buttersworths Scientific Publications, London. 1957. $8.80.*

These papers reflect the first attempt in Great Britain to bring together people engaged in process dynamics research (measurement and control specialists) and people with practical experience in operating plants. The aims of the conference were to: establish facts about existing plants and processes; use these facts to develop a rational basis for predicting characteristics of plants in the design

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stage; and suggest new methods of design and control to improve product quality and plant efficiency. Though most papers come from the chemical and petroleum industries, many things they say can be applied to other areas of industry.

[CONTROL ENGINEERING's London reporter, John Tunstall, gave a first-hand report of the conference in the June 1956 issue, page 17. And page 159 of the same issue contains an abstract of the most significant paper at the conference—the one by H. Voetter of Royal Dutch Shell on the control of distillation columns—which is printed in full in the present book along with discussion on the paper by conference attendees. Ed.]

Also covered in this book are: dynamic characteristics of the distillation-column reboiler, transient response of a distillation column, data-reduction equipment as a tool in plant analysis, an analog computer study of an operating process control loop, measurement of dynamic responses of plant units, and process dynamics from normal plant records. Some comments from conference attendees are included. These shed additional light, often by virtue of severe disagreement, on the statements and conclusions of the speakers.

WHAT'S AHEAD: MEETINGS

JUNE

Association for Computing Machinery, Twelfth Annual Meeting, University of Houston, Houston, Tex. June 19-21

American Institute of Electrical Engineers, Summer General Meeting, Sheraton-Mt. Royal, Montreal, Quebec, Can. June 24-28

British Institution of Radio Engineers Convention, Theme—"Electronics in Automation", University of Cambridge, (9 Bedford Sq., London, W. C. 1) June 27-July 1

AUGUST

Institute of Radio Engineers, Professional Group on Automatic Control, Fairmount Hotel, San Francisco Aug. 9

American Society of Mechanical Engineers, National Conference on Heat Transfer and Industrial Exhibit, Hetzel Union Building, Pennsylvania State University, University Park, Pa. Aug. 11-14

Radio-Electronics Television Manufacturers Association (RETMA) Symposium on Numerical Control Systems for Machine Tools, Ambassador Hotel, Los Angeles Aug. 17-18

Western Electronic Show and Convention (WESCON), Fairmount Hotel and Cow Palace, San Francisco Aug. 20-23

American Institute of Electrical Engineers, Pacific General Meeting, Pasco High School, Pasco, Wash Aug. 26-30

Instrument Society of America, First International Symposium on Gas Chromatography, Michigan State University, Kellogg Center, East Lansing, Mich. Aug. 28-30

SEPTEMBER

Institute of Radio Engineers, PGIE, 2nd Special Technical Conference on Magnetic Amplifiers. Hotel Penn Sheraton, Pittsburgh Sept. 4-6

Instrument Society of America, 12th Annual International Conference and Exhibit, Cleveland Auditorium, Cleveland, Ohio Sept. 9-13

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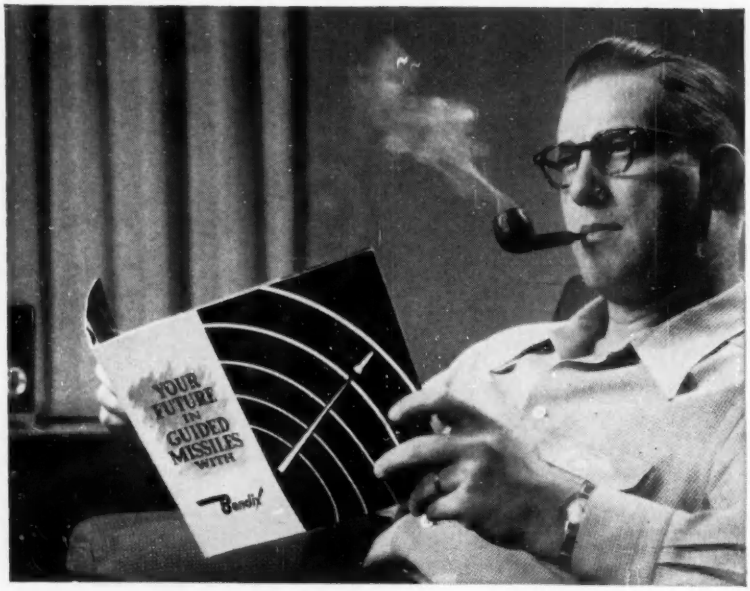

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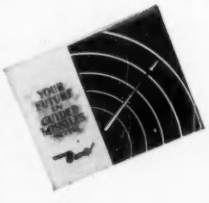

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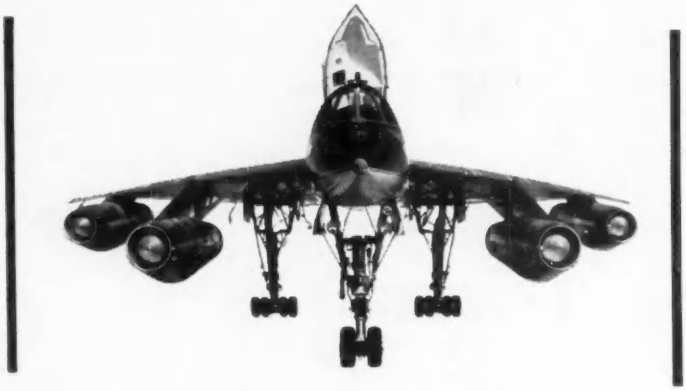

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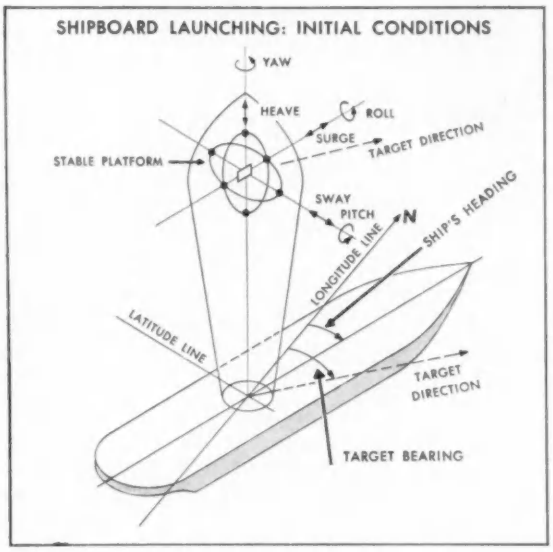
New Group Forming as Missile & Ordnance Systems Department of G.E. Adds Navy Project to Nose Cone Development Program.

POLARIS is the most challenging development undertaken by industry for the Navy since the nuclear propulsion program. It is an Intermediate Range Ballistic Missile, whose specifications call for launching capability from both surface vessels and submarines.

PROBLEMS UNIQUE IN MISSILE TECHNOLOGY



The diagram above presents the primary parameters involved in shipboard launching of a ballistic missile in its simplest form.

For Polaris, MOSD must not only surmount these initial conditions but solve fire control problems more complex than heretofore encountered. Pinpoint accuracy in missile guidance is an impressive accomplishment under the most favorable conditions. But how do you achieve it with a missile hurled from a moving platform and aimed at an object approximately 1,500 nautical miles away?

In addition, the Polaris guidance and fire control systems must also operate effectively under the difficult conditions created by submarine launching.

HOW IS MOSD EQUIPPED TO SOLVE THESE PROBLEMS?

As prime contractor for IRBM and ICBM Nose Cone Development, MOSD can draw on a reservoir of top level experience and skill. This G-E department also has a backlog of significant experience in the development and manufacture of Naval Fire Control Equipment, such as range-finders, computers and radar antennas.

NEW OPPORTUNITIES FOR ENGINEERS WITH EXPERIENCE IN THE DEVELOPMENT OF GUIDANCE & FIRE CONTROL SYSTEMS

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GUIDANCE & CONTROL SYSTEMS

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Engineers and Scientists with experience in other areas of Electrical Engineering, Aeronautical Engineering. Aerodynamics, Mechanical Engineering, Physics or Mathematics should inquire about positions on other missile programs at Missile and Ordnance Systems Department.

AN INVITATION

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Please send resume to Mr. John Watt, Room 595-10 MOSD

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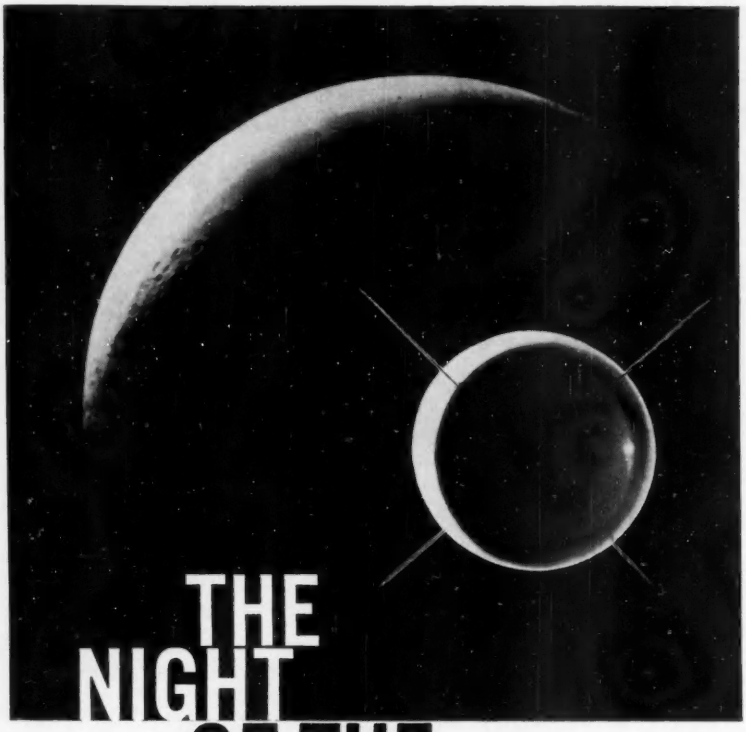

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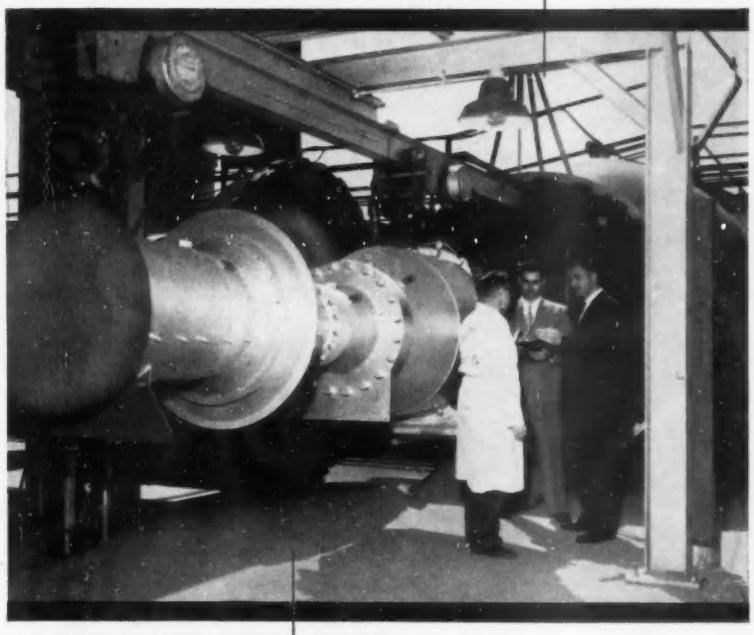

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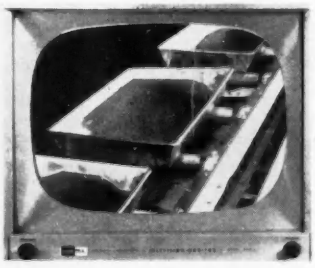

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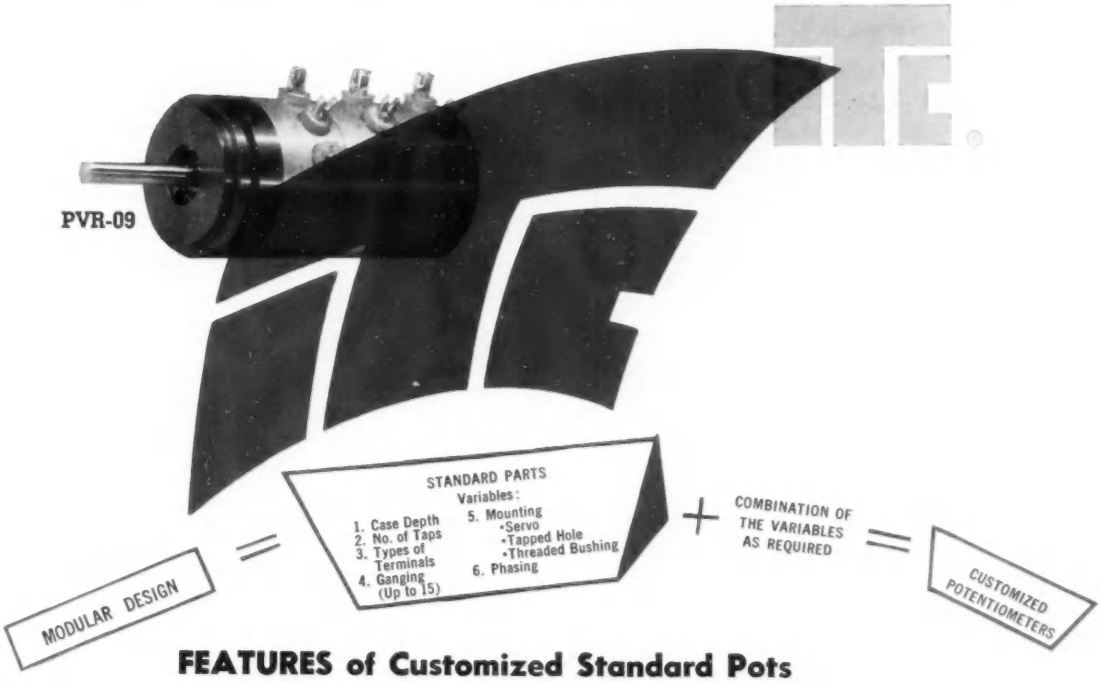
NEW MODULAR DESIGN PRECISION POTENTIOMETER



FEATURES of Customized Standard Pots

High Temperature Operation . . . to 145 deg C
Independent Linearity of +0.25%
Non-linear Functions

The newly developed TIC Type PVR-09 incorporates *modular* design for choice of cup depth, mounting, and number of taps. Modular design, a new concept in manufacturing, makes available all mounting types — servo, tapped hole, and threaded bushing . . . and, in addition provides extreme flexibility in customizing the standard PVR-09 design to the individual application.

Ganging up to 15 cups, without external clamps, and each individually phased at the factory also provided by the modular design technique. Up to 9 taps are available in a standard unit — others on special order. Ball bearing construction provides low torque.

PERTINENT CHARACTERISTICS:

- **STANDARD RESISTANCES:** 100 ohms to 150K
- **ACCURACY OF TOTAL RESISTANCE:** ±5% on standard, to ±1% on special linear functions
- **INDEPENDENT LINEARITY:** ±0.5% of total R above 5K standard, ±0.25% on special
- **POWER RATING:** 1.25 watts at 85°C
- **RESISTANCE FUNCTIONS:** Can be provided with a variety of non-linear functions
- **TAPS:** Up to 9 taps . . . with 10 deg
- **TEMPERATURE RANGE:** −55 to +145 deg C
- **MILITARY SPECIFICATIONS:** Tested to MIL-E-5272A

With our new plant facilities and unique modular design techniques you now can get *customized* design without delay. Complete spec's on request.

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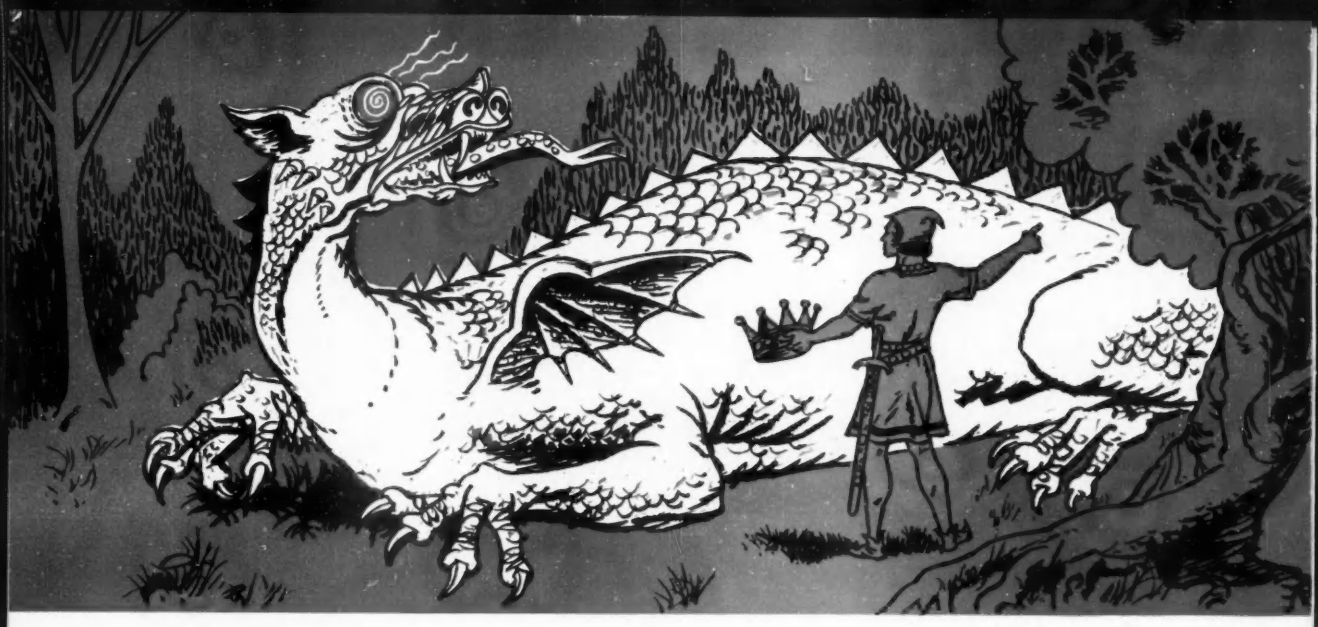

THREE BROTHERS and the WICKED DRAGON

Once upon a time there were three brothers . . . Ready, Willing, and Able. Ready, the eldest, was a man of great eloquence who would make fine speeches at the least provocation. The next in age was called Willing. His sword and spear were the willing servants of every noble cause. The youngest of the three was called Able. A level headed lad was he with an able wit and pleasing manner.

Not content to stay at home, the three brothers set out to make their fortunes in the world. They traveled long days and nights over high mountains and into deep valleys, until, at last, they came to a village where there was much sorrow and weeping. Inquiring after the cause, the three brothers soon discovered that a wicked dragon was terrorizing the countryside, bringing death and destruction to villages far and near. So fierce and terrible was this dragon that the king promised much wealth and the hand of his daughter to the man who would successfully challenge him.

The brothers went straight to the king to offer their services. The king thanked them and sent them in search of the dragon with this brief advice . . .

"A well made plan spiced with steel
Does many a happy conclusion seal."

"The meaning of this advice is clear," said Ready. "A well planned argument spiced with the cold steel of logic will surely dissuade the dragon from his present purposes, and so bring this matter to a happy conclusion." Armed only with words, Ready went out in search of the dragon. Upon meeting the dragon, he began his argument in the most beautiful, flowing language . . . but the impolite dragon concluded the lengthy argument with a rude gulp. Oh, unhappy brother, where is thy logic now?

Willing was next to try his luck. "A thoughtful battle plan is called for here," he said. "A well executed maneuver, followed by a swift frontal attack will surely win the day." But, alas, his plan likewise failed. For in direct combat, the sword is no match for the mighty dragon.

Able knew why his brothers had failed and so made his plans accordingly. He based his scheme on the well known fact that dragons have a streak of vanity that's as wide as the ocean and as long as a hot summer's day. And so with plan and sword, he went in search of the dragon. While he walked he cried out in a loud voice over and over again— "Dragon, dragon, receive thy crown."

The dragon soon heard the cry and came running—"What crown is this?" he asked. "Why the crown that will proclaim you king of the beasts," said Able. Seeing that the dragon was taking the bait, Able continued—"But, first, you must prove that you are swifter than the wind, stronger than a thousand horses, and hast vision greater than the golden eagle." "Just try me," said the confident dragon.

"If you can run to yonder tree and back before I breathe my next breath, thou art truly swifter than the wind." The dragon did this with time to spare.

"If you are able to shake yonder mountain, thy strength is truly greater than a thousand horses." With a single blow of his mighty tail, the dragon shook the mountain with such force that the very earth did quake.

Now all this was done in order to trick the dragon into completing the last of the three trials. Able began slowly— "On the sun there lives a dragon with one eye. If you can tell me the color of this eye, thy vision is truly greater than the golden eagle."

The dragon boldly stared at the sun. After a while he said, "I see nothing but fiery red." "Keep looking," said Able. And then a little while later, the dragon said, "I see bright yellow." "Keep looking," said Able as he moved closer and slowly drew his sword. And still a little later—"I see brilliant white, now" said the dragon. "Keep looking," said Able as he moved still closer. And then finally the dragon said, "I see black, all is black!" With these words, Able up and slew the dragon with a single blow of his sword.

Peace and contentment once again reigned in the land. Able received the great fortune promised him and later married the king's daughter. And from that day to this ne'er a dragon has been seen in that happy kingdom.

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